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CENTRE DE PHYSIQUE ÉLECTRONIQUE ET CORPUSCULAIRE

DOMAINE DE CORBEVILLE par ORSAY (Seine-et-Oise)

CONTRACT C.S.F. - A.R.D.C.

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STATUS REPORT Nº 4

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RESEARCH ON 8 MILLIMETER M-TYPE CARCINOTRON TUBES

April 1961

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A B S T R A C T

A B S T R A C T

The tests of three circular tubes are described. A number of modifications are discussed. A new type of output is described. The program is defined.

-:-:-

DETAILED REPORT

I. TUBE TESTS

I.1. TUBES CM ' . .A Nº 1 AND 2.

Tubes Nº 1 and 2 were built according to the drawings of the status raport Nº 2 with the modifications given by figures 15 and 16 of status report Nº 3. Furthermore, the pole pieces of tube Nº 2 were flattened (0.5 mm) because it was thought that the focusing action of the radial component of magnetic field was too strong in tube Nº 1. Figures 1 and 2 show the axial magnetic field versus radial distance with the pole pieces of the two tubes. Figure 3 gives some of the critical dimensions measured in the tubes.

None of the tubes was satisfactory as far as the dimensions of the ridge are concerned, as the crowns moved slightly apart during brazing. The ridge gaps were respectively 0,139 and 0,129 mm instead of 0,060.

Figures 4 and 5 are plots of the VSWR. In spite of the wrong dimensions, tube 1 was well matched. Though the values are generally not taken at the same frequencies, it seems that the presence of the sole and gun do not affect the VSWR, showing that little power is radiated by the ridge transformer. This is also supported by the fact that the tubes radiated very little through the leads in contrast with CM 08 tubes.

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Photos 1 to 6 show various parts of the tubes at different stages of the tests.

The cathodes (type 103 CSF) were somewhat difficult to activate, but worked well, and the tubes proved in general satisfactory as far as technology is concerned.

Figure 6 shows the output power, beam current and tuning range of tube nº 1. The points of measurement were chosen at the peaks and valleys of the output power. The tube tunes to high frequencies, but with a very sharp decrease of output power.

Figure 7 shows power output versus beam current. The small ondulations of the curve are due to slight variations of line voltage and frequency as shown in figure 8 where the frequency was measured.

Maximum power obtained at a single frequency was 7 watts at 31,400 Mc/s at 1500 volts and 127 mA, with 3,7 % efficiency.

The tube deteriorated progressively by arcing during attempts to improve over these figures.

Photo 5 shows the damages on the circuit and the moly ridge, suggesting that a good amount of current was lost near the gun.

Concerning now tube Nº 2, figures 9 and 10 show output power and wavelength versus line voltage for two different sole voltages. The tuning curves are not regular. If one superimposes them with a shift of 100 volts for the line voltage, thus compensating for the difference in sole voltage, the tuning curves

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superimpose only down to 9,4 mm. From this value down to 8,4 mm, they are distinct. Actually, it often seemed on the scope showing the rf envelope that there was competition between two modes of oscillation. Unfortunately, the VSWR of the tube had not been measured above 9.2 mm.

Maximum output power at a single frequency was 7.4 watts with 1350 V, 199 mA at 10.25 mm, with an efficiency of 2.7 %. The tube deteriorated like tube 1.

Both tubes were similar in many respects. Both were often noisy even after a few hoursof operation. They were operated for about ten hours.The most significant difference is the tuning range, which did not extend to the higher frequencies in tube 2. This is probably due to the optical system. Tube 2 had a smaller cathode-anode distance (figure 3).

When the tubes were opened, they were damaged in much the same way. (photos 5 and 6). The collectors were apparently very inefficient and there were indications of electron bombardment on the pole pieces in the space between the collector and the gun.

Other observations will be described now.

I.2. CENTERING AND THERMAL EXPANSION OF THE SOLE.

In both tubes, the sole centering device proved very effective, but not always handy. Small displacements could be obtained, but generally not as expected. On tube Nº 1 data were taken after two careful alignments. From the tuning curves it can be infered that the sole-anode distance differed by about 0.01 mm. Measurements on the CM 08 had shown that the distance should be controled within 0.005 mm. Thus the centering system must be made more accurate (see later).

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On tube Nº 2, frequency drift was measured. In 30 minutes the tube reached stable operation. The frequency drifted from 28,600 to 31,100 Mc/s, while the sole anode distance must have varied from 0.282 to 0.250 mm. The distance measured under the microscope is 0,281 mm (see table figure 3). This corresponds to a temperature rise of 400ºC for the sole if the anode is supposed to remain at the same temperature. In order to reduce the drift, a shorter ceramic support was designed for the subsequent tubes.

I.3. MAGNETIC FIELD AND ELECTRON OPTICS.

Figure 1 shows a plot of magnetic field versus radial distance for the pole pieces used in tube Nº 1. The anode diameter is indicated by two vertical lines. The field was not the same on the two halves of the circumference. Since the circuit occupies only 120º, it was easy to avoid the effect of azimuthal non-uniformity. In the vicinity of the peaks, the equation of the field is approximately

$$H_z = H_0 \left[1 - \left(\frac{r - r_0}{a} \right)^2 \right]$$

The radial component is given by

$$H_r = - H_0 \frac{(r - r_0) \times 2Z}{a^2}$$

This component has a focusing effect and varies linearly from one edge of the sole to the other. From figure 1, we find

$r_0 = 1.4$ cm
$a = 1.0$ cm

....

Thus, for Z = 0.1 cm, r = 1.6 cm, we have

$$H_r = - 0.04\ H_o$$

The absolute value is of the order of 300 oersted. In a field of this magnitude, electrons with a velocity of c/20 will turn with a radius of about 0.3 cm. Thus, the focusing action is quite pronounced. On photo 5, it can be seen that the beam of tube № 1 was very well centered and much narrower than the circuit. It was thought better to decrease this effect.

For tube № 2, the lips of the pole pieces were cut down flat on 0.5 mm in the Z direction, and their distance increased to 9 mm. Figure 2 is a plot of the magnetic field. It has now azimuthal uniformity. One now has

$$r_o = 1.42 \text{ cm}$$
$$a = 1.06 \text{ cm}$$

The image of the beam on photo 6 shows that the beam started off side and turned to the other side where it stayed for about a third of its trajectory, and came back to the center. There must have been another effect to maintain the beam off center.

In the two tubes, the edge of the sole opposite to the cathode was distorted by the heat of the latter. This has certainly affected the launching of the beam. In the future, one plans to use arc melted molybdenum.

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I.4. <u>TUBES CM 07 CB Nº 3 AND 4</u>.

These two tubes were designed and machined together, but tube Nº 4 was stopped for modifications after the tests on tube Nº 3. Originally, the only difference was that tube Nº 3 had a smooth sole, without the side rails. The magnetic field had proved quite efficient to control the beam in the axial direction and these rails enhance arcing.

These two tubes differed from tubes 1 and 2 in the following respects.

- The sole diameter was nominally 0.1 mm smaller.

- The sole had a knife shaped section which should be more efficient than the collector, since it will disperse the electrons axially (figure 11).

- A moly anode block was inserted between the ridge and the plate in order to collect ill-focused electrons and to protect the first fingers (figure 12). The sole was modified accordingly (figure 11).

- The ceramic support of the sole was shortened and thickened in order to increase heat conductivity (figure 13).

- The pole pieces were modified (figure 14). A plot of the magnetic field can be seen on figure 15.

One now has $r_0 = 1.43$ cm, $a = 0.95$ cm.

On the whole, the three sets of pole pieces are fairly similar in this respect. Figure 16 shows the magnetic field versus current plot of the three sets of pole pieces used so far in the same electromagnet. Set Nº 2 is perhaps équivalent to nº 1 for the same gap but set nº 3 is markedly inferior for fields in excess of 6000 Oersted.

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- The cathode was turned 90º arround its axis : the moly edges that hold the emissive materiel are now parallel to the edge of the sole and to the magnetic field, so that the edge of the cathode that faces the interaction space is now non emissive. Furthermore, the radius at the cathode surface was about 0.05 mm higher (that is, in direction of the positive electrodes) than at the sole level. When the cathode is hot, the difference is still greater.

- The external sole centering device was made of duraluminum instead of steel (weight) and the ring between the titanium shell and the centering steel balls was made out of stainless steel, and screwed to the shell instead of fixed on it by spring action

- During brazing of the interdigital lines, about half of the attenuated part of the line, on the collector side, was filled with brazing.

- Finally, while tubes Nº 1 and 2 were maintained at 430ºC for two hours during bake-out, tube Nº3 was maintained for about five hours, until the pressure went down to 10^{-6} mm Hg.

Figuro 17 is a plot of VSWR versus wavelength in the cold tube.

The cathode was very easy to activate and emitted quite well all the time.

Figures 18 and 19 are plots of output power and wavelength versus line voltage for two values of beam current. Since the results were no better at 200 mA than at 180 mA, plots of output power versus beam current were taken for three values of beam voltage, which were kept as constant as possible, but not enough to avoid the ondulations seen of the curves (figure 20). It might have been possible to obtain more power at 7.60 mm by increasing the current, but not at 7.87 mm, and this was deemed dangerous for the tube.

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This tube operates at substantially lower magnetic field than the CM 08's and the first two CM 07's : 5,800 Gauss instead of 6,800 and 8,000. It could have operated with the magnets shown on photo 11 in status report Nº 3. The weight of the whole unit would have been about 11 ℓb :

Tube proper	1560 g
Stainless steel ring	150 g
Centering device (duraluminium)	380 g
Magnets 2 x 1350 g	2700 g
Intermediate pole pieces: 2x80g	160 g
Total	4950 g

The reason for this low magnetic field is perhaps the location of the sole with respect to the cathode : perhaps the trajectories are linear at high voltage and the magnetic field can be lowered without losing current to the anode (Hull cut-off). More important is the large sole-anode distance that can be calculated from figures 18 and 19 and from cold propagation data. Figure 21 is a plot of the distance versus applied power, calculated by neglecting space charge or current pushing effects.

It can be seen that it raises with applied power. It may be that, actually, the magnetic field is decreasing. Otherwise, the anode would be expanding faster than the sole, on the sole would move off center. However, the results on tube 2 indicate that the sole was almost exactly centered when optimum power was obtained. Anyway, there is a hope of cancelling out thermal frequency drift by adjusting the natural sole cooling.

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The most striking feature of the tube is that it oscillated up to 43,500 Mc/s with a few watts output and that maximum power obtained at a single frequency was 15 watts at 40,000 Mc/s.

The tube had some discontinuities but it was generally not so noisy as the first two.

After some time, the adjustment of the sole did not respond properly, a few arcs occured and power went down.

After opening the tube, the circuit was intact, but the anode block had partly melted. It is probable that a good amount of beam current was still lost on the anode block. The poor operation of the centering device led to stop tube Nº 4 and to provide it with the new titanium membrane, brazed pole pieces and a shield preventing leaks from the cathode to the pole pieces. Tube Nº3 can also be rebuilt in the same fashion.

In tube Nº 3, it could also be seen that the current had not left the gun along the center line of the sole, but that it had also an important component of velocity in the direction of the axis of the tube. This may be due to a slight lack of parallelism between cathode and accelerating plate. The beam remained on the side of the circuit for an appreciable length of its path (see photo 7). The sole surface was slightly swollen in the vicinity of the gun, a further reason to look for better molybdenum.

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II. TECHNOLOGICAL STUDIES

II.1. HOBBING.

Further tests to form the main crown with a thin fin inside as described previously have not been successful. Perhaps the slot in the hob that corresponds to the fin was not polished very well. Another test is being prepared but, if the fin cannot be obtained, the second hobbing operation at right angle to the first one, will nevertheless be tried. If this is successful, the ridge would have to be brazed at the same time as the circuits.

An interdigital line with fingers 13/100 mm thick has been made in another laboratory of the Company. There is some hope of going down to 0,08 mm.

II.2. SOLE SUPPORT.

Besides the shorter ceramic shown on figure 13, a more rigid membrane ("second membrane") was designed (figure 22). It is made out of titanium, is brazed directly to the pole piece. A dummy tube containing this membrane was built, baked, and sealed off with a vacuum gauge. The brazings were successful. The rigidity of the membrane is appropriate. This membrane will be used on tube Nº 4 and on tube Nº 3 when it is rebuilt (figure 23).

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A third system of sole support was designed (figure 23). It includes a smaller number of parts and brazings and should be about three times more accurate since the membrane is closer to the sole.

II.3. NEW CATHODE DESIGN.

Figure 24 shows the new cathode design, where the molybdenum cylinder is held and surrounded by a very thin cylinder of tantalum. This should decrease radiation and conduction of heat away from the cathode and thus decrease the thermic expansion in the sole.

II.4. TITANIUM PUMP.

Figure 25 shows the design of a titanium pump that will be inserted between the tube and the diffusion pump. Copper tubing will be used. The pump and tube will be sealed off after baking. The pump will be sealed off after the tests of the tube.

II.5. CERAMIC WINDOW.

The brazing of the ceramic window to copper guide is not always successful. Tests are continued. The tubes still use a glass window and this is the only thing that prevents from baking them at 600 or 650ºC.

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III. COLD TESTS

III.1. DIRECTIONAL COUPLER OUTPUT.

The principle of a new type of rf output is being studied. It uses a short section of interdigital line placed parallel to the main line on the side opposite to the sole. In the region where there are two lines, the propagation separates into an asymetrical and a symetrical mode, which beat over a quarter of a cycle. This forms a directional coupler.

This output should radiate much less through the gun electrodes, lead to a more uniform electron bombardment of the line, and leave more freedom for the choice of the shape of the ridge coupling the shorter line to the wave guide. The resulting complication is not considerable at least for linear tubes.

This type of directional coupler was tried at scale 10 with the two brass lines described earlier (schematic of Fig.26). The separation between the two lines could be varied as well as their common length.

A constant rf input at constant frequency was fed to one of the circuit. Figures 27 and 28 are plots of the power detected in the output of the other circuit with the common length in abscissa. Measurements were taken at 3740 Mc/s for 2 mm spacing and at 3700 Mc/s for 5 mm spacing. They are diffi cult to interpret because of the rapid changes of transmission due to the periodicity of the circuits. Furthermore, it was checked that when there is maximum power in the output, no power is propagated at the loose end of the input line.

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For a geometry giving maximum transmission at a single frequency, the transmission was measured as a function of frequency by the method indicated in the schematic of figure 29. The results are given on figure 30.

Maximum transmission is 45 % with brass lines and 70 % with silver plated brass. This may be due to losses.

III.2. MEASUREMENT OF LOSSES.

In order to measure losses in the actual circuit of the tube, a model with an input and an output of the usual type is being built.

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IV. LINEAR TUBES

Two linear tubes of the new design (CM 07 LA) are being built (figure 25, 3d. status report). They are being modified in order to add the anode block first used in CM 07 C3. They should be completed in the first days of May. The electro-magnet of the CM 08 is being modified to accomodate the new design

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V. CONCLUSION AND PROGRAM

Three circular tubes have been built and tested. Their technology is considered much superior to that of the CM 08. These first three tubes have operated as average successful CM 08's. However, the tuning range of the third tube extended up to 43,500 Mc/s with a few watts and delivered 15 watts at 40 000 Mc/s. The efficiency is only about 3 % and it seems that a substantial amount of current is lost directly from the cathode to the pole pieces.

The fourth tube has been stopped for modifications.

Two more circular tubes will be assembled as soon as the results are available, and will have a more accurate centering system.

Tests a hobbinh, propagation, etc .... are continuing.

Two linear tubes are nearing completion. This design will not be pursued unless it proves to have substantially better performance than the circular design, which are much easier to manufacture.

The packaged circular tube might weigh as low as 11 ℓb

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F I G U R E S

LIST OF FIGURES

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LIST OF PHOTOS

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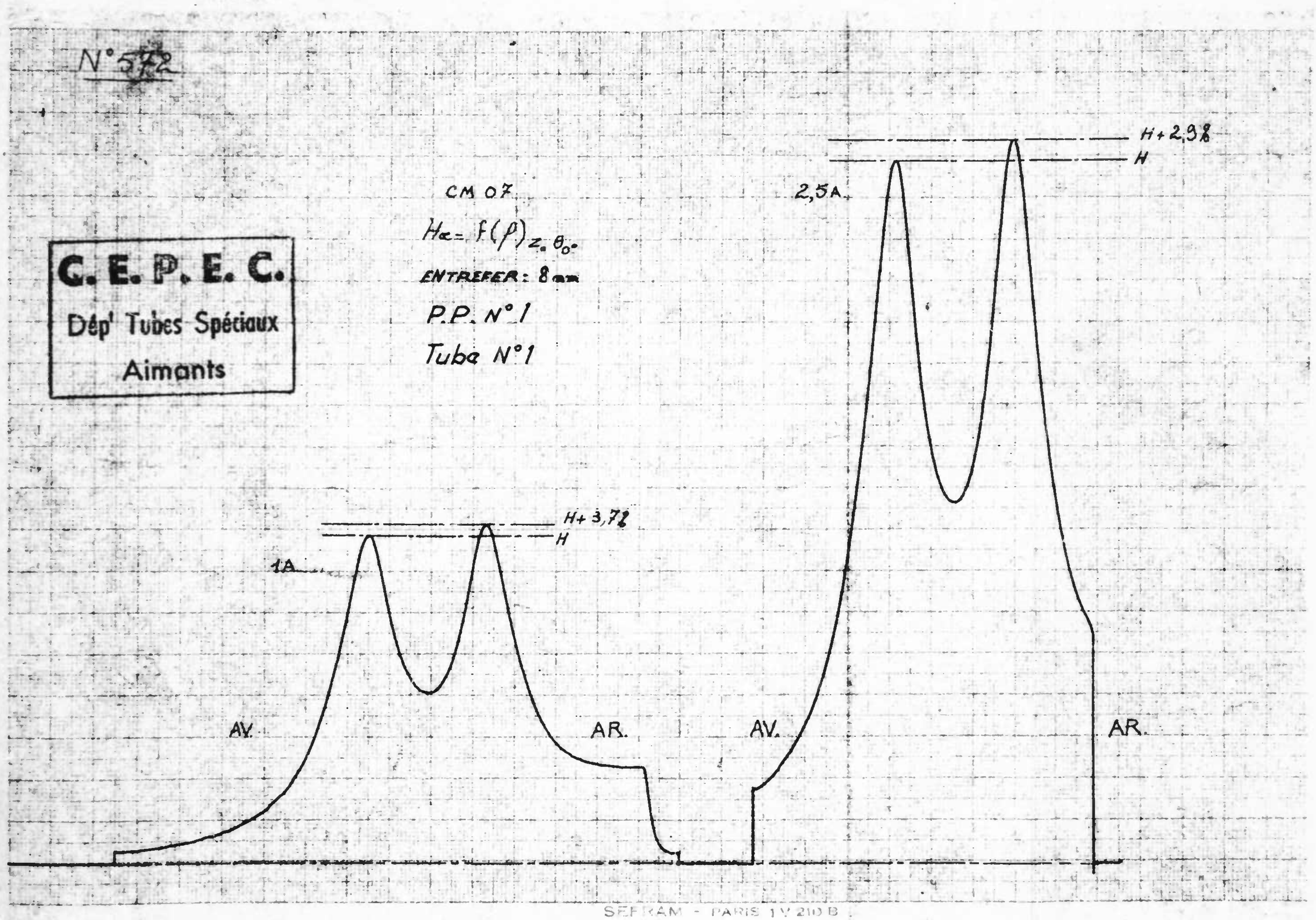

N°572
C. E. P. E. C.
Dép' Tubes Spéciaux
Aimants
CM 07
Hα = f(ρ) z. θ0°
ENTREFER : 8 mm
P.P. N°1
Tube N°1
H+3,7%
H
1A
AV.
AR.
AV.
2,5A
H+2,9%
H
AR.
SEFRAM - PARIS 1 V 210 B

Fig. 1

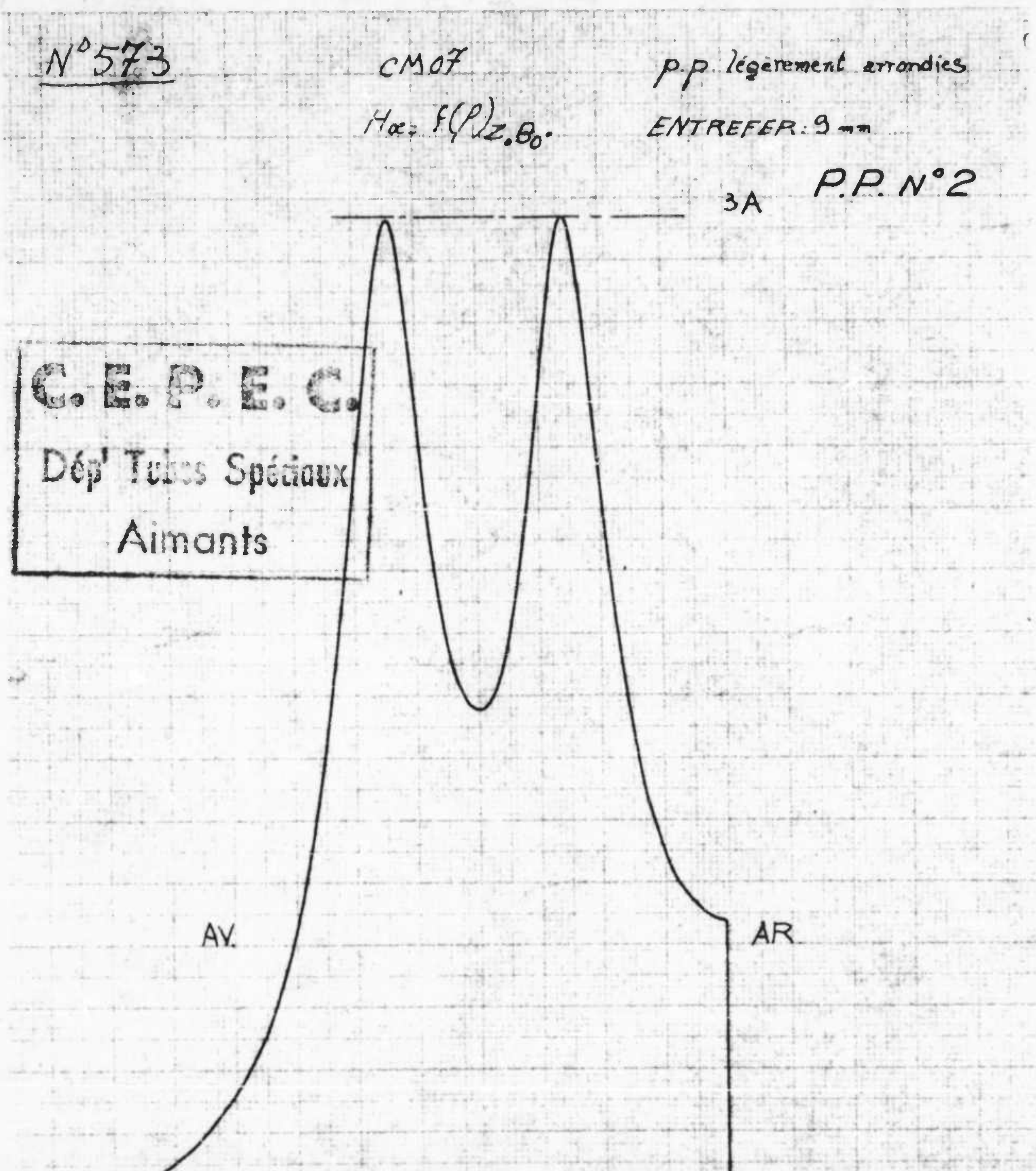
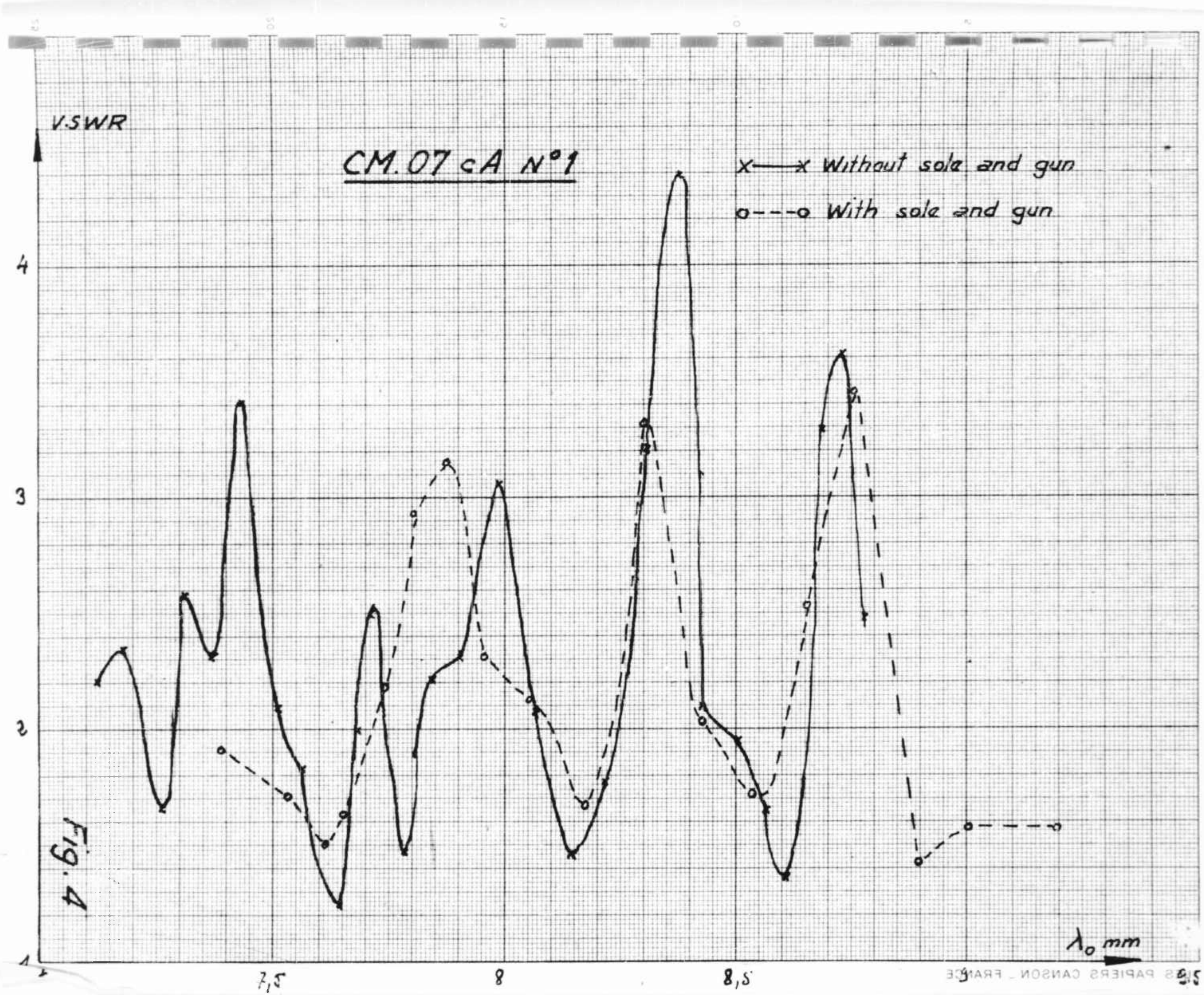

N°573
CM07
$H_\alpha = f(\rho)_{Z,B_0}$
p.p. légèrement arrondies
ENTREFER : 9 mm
P.P. N°2
3A
C. E. P. E. C.
Dép' Tubes Spéciaux
Aimants
AV.
AR.

Fig. 2

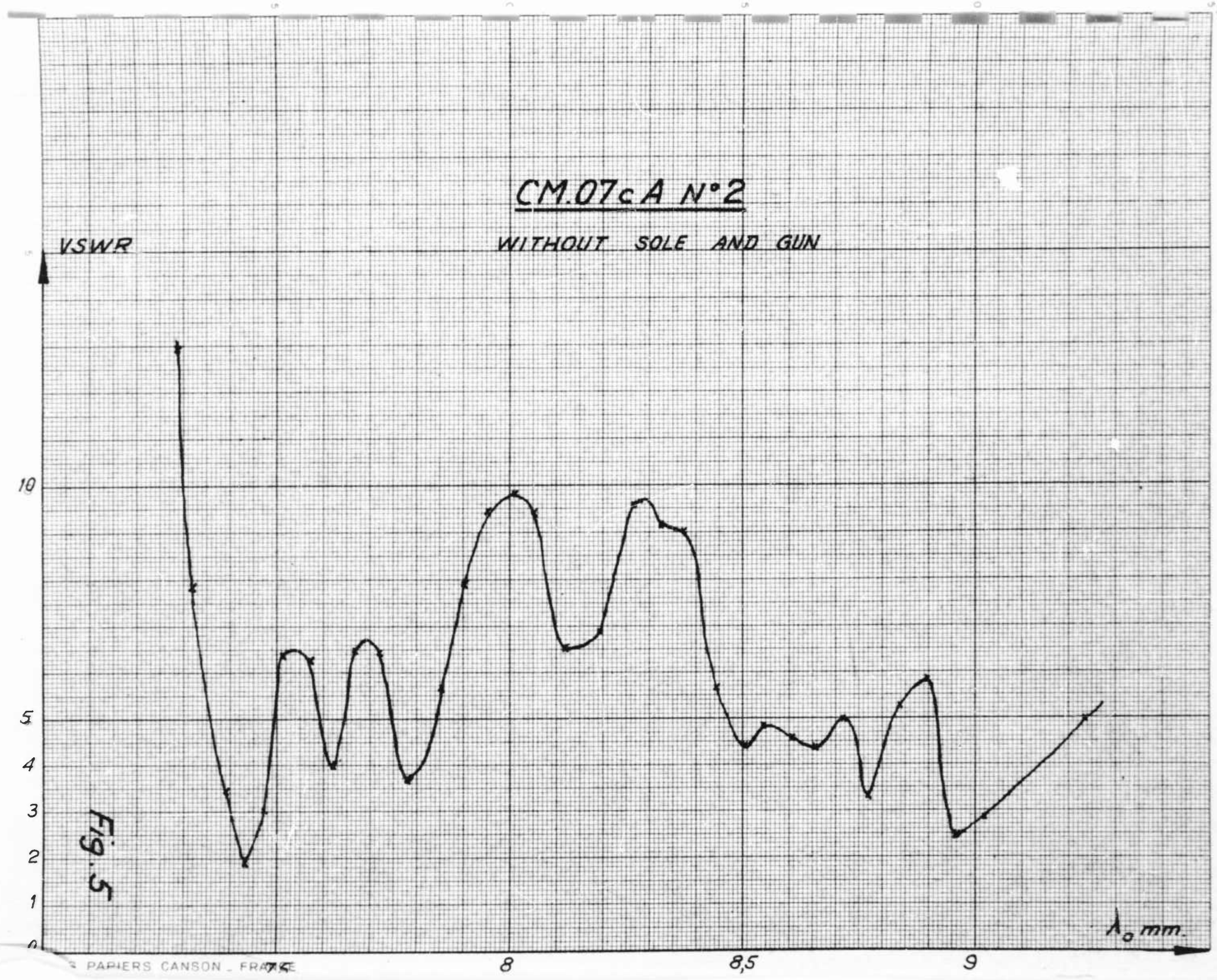
CM 07c N°	Circuit DIA	Sole edge DIA	Sole DIA	Sole circuit distance cold	hot
1	31,978	31,590	31,415	0,305	0,22
2	32,003	31,590	31,392	0,281	0,25
3	32,000	31,300	31,300	0,300	0,344

Fig. 3



V.SWR
CM.07 cA N°1
x——x Without sole and gun
o- - -o With sole and gun
4
3
2
1
7,5
8
8,5
9
9,5
λ_o mm

Fig. 4



CM.07c A N°2
WITHOUT SOLE AND GUN
VSWR
10
5
4
3
2
1
0
7,5
8
8,5
9
λ_o mm.
PAPIERS CANSON - FRANCE

Fig. 5

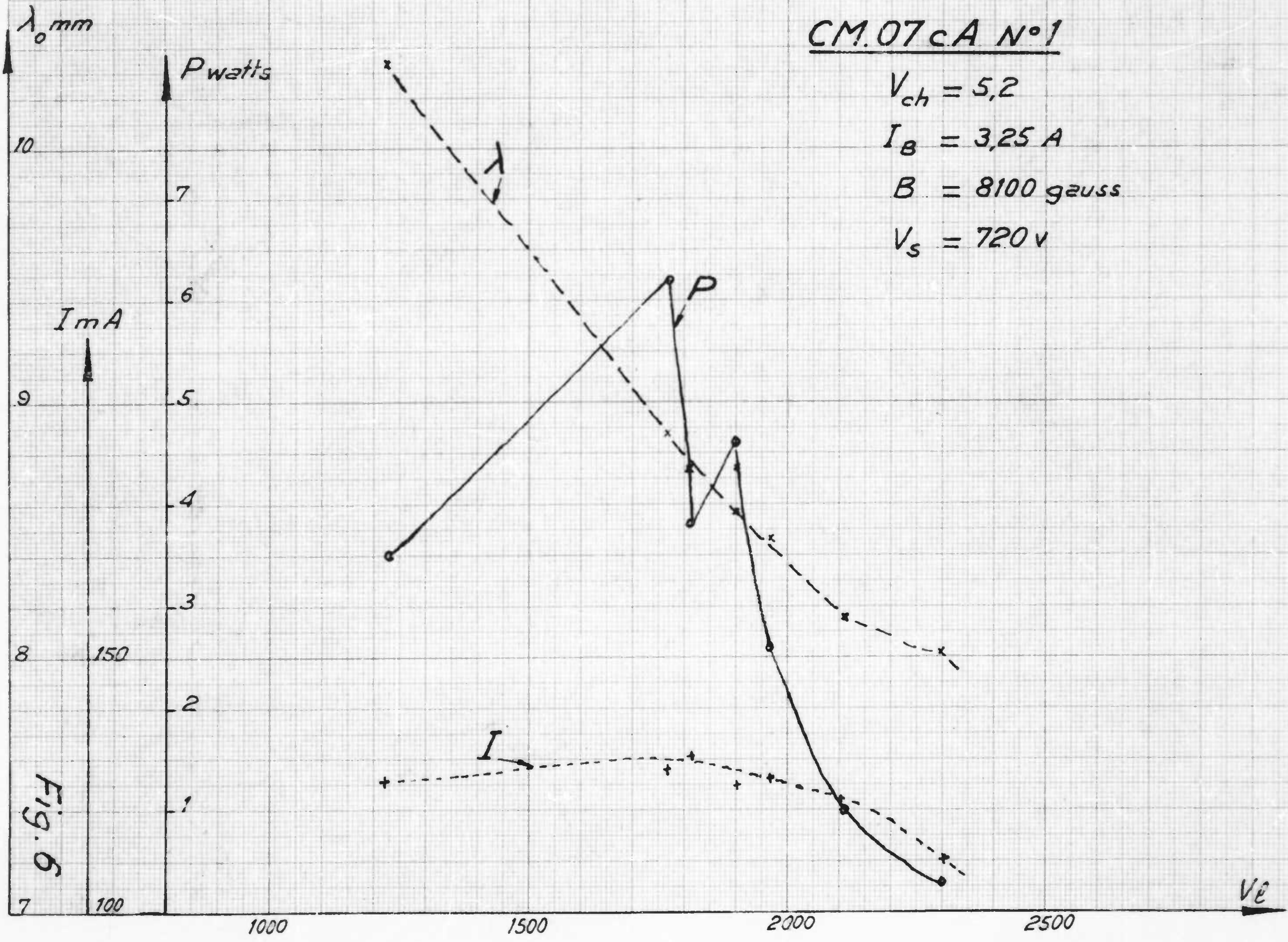

CM.07cA N°1
$V_{ch} = 5,2$
$I_B = 3,25\ A$
$B = 8100$ gauss
$V_s = 720\ v$
λ_o mm
P watts
I mA
λ
P
I
Vℓ
10
9
8
7
7
6
5
4
3
2
1
150
100
1000
1500
2000
2500

Fig. 6

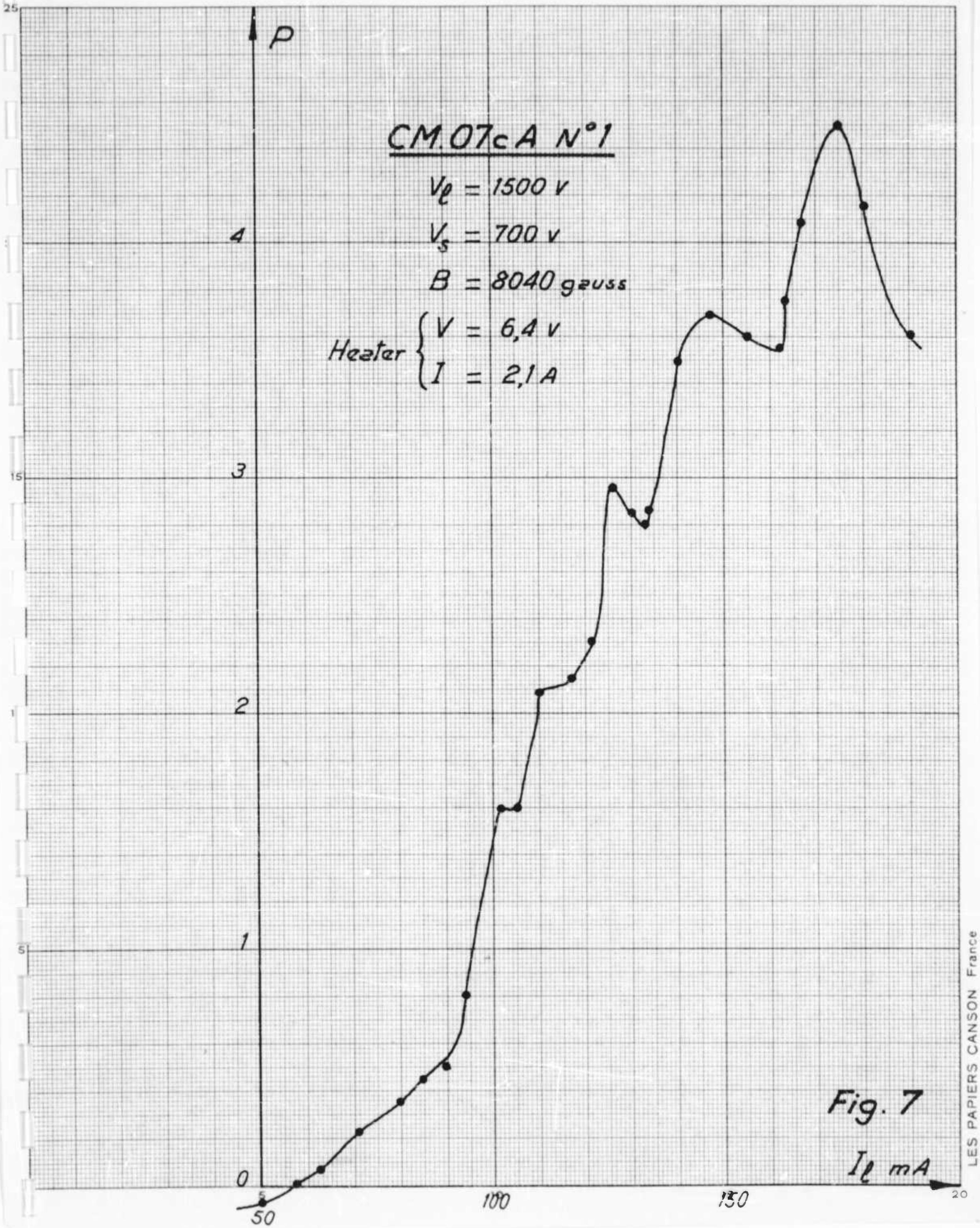
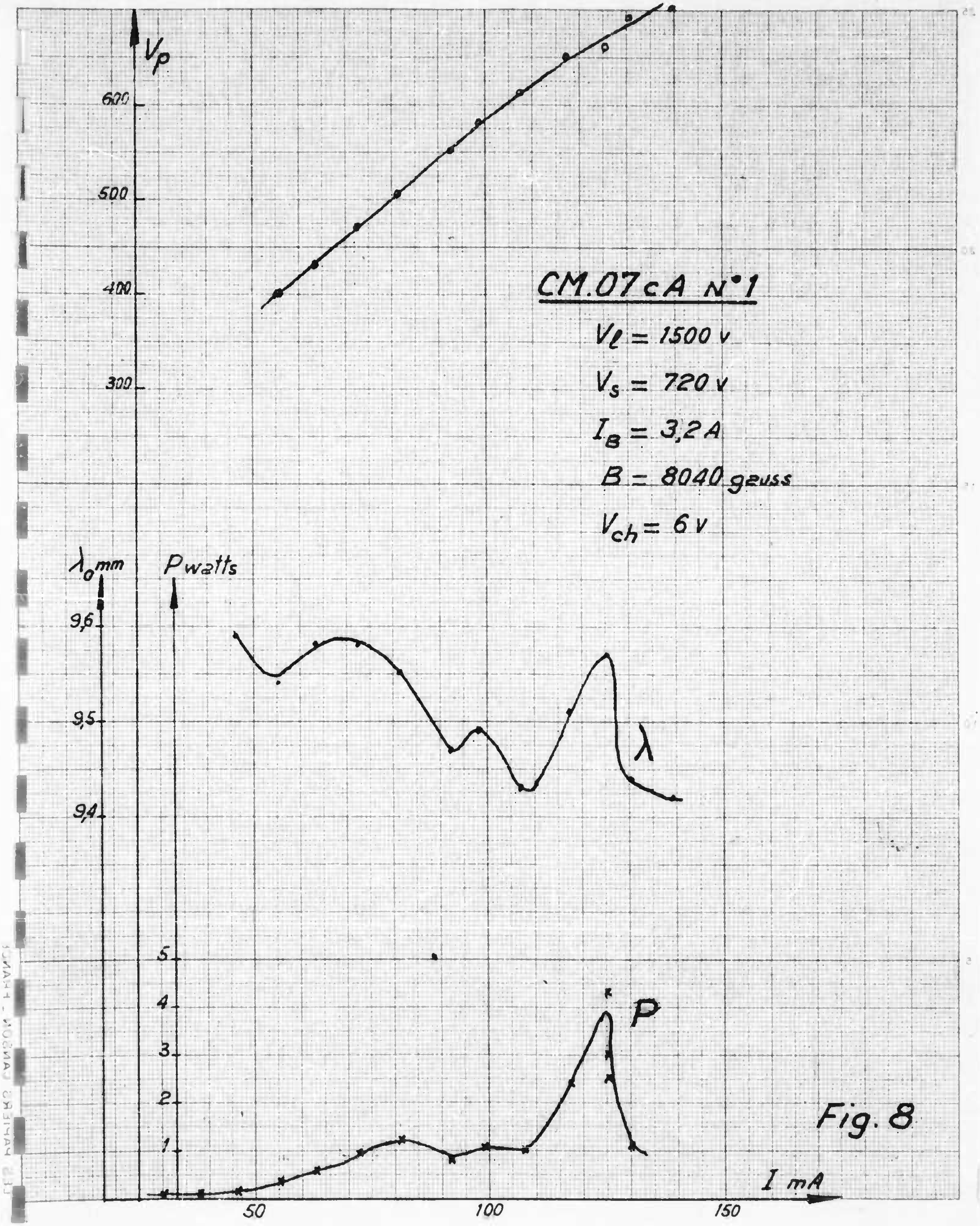
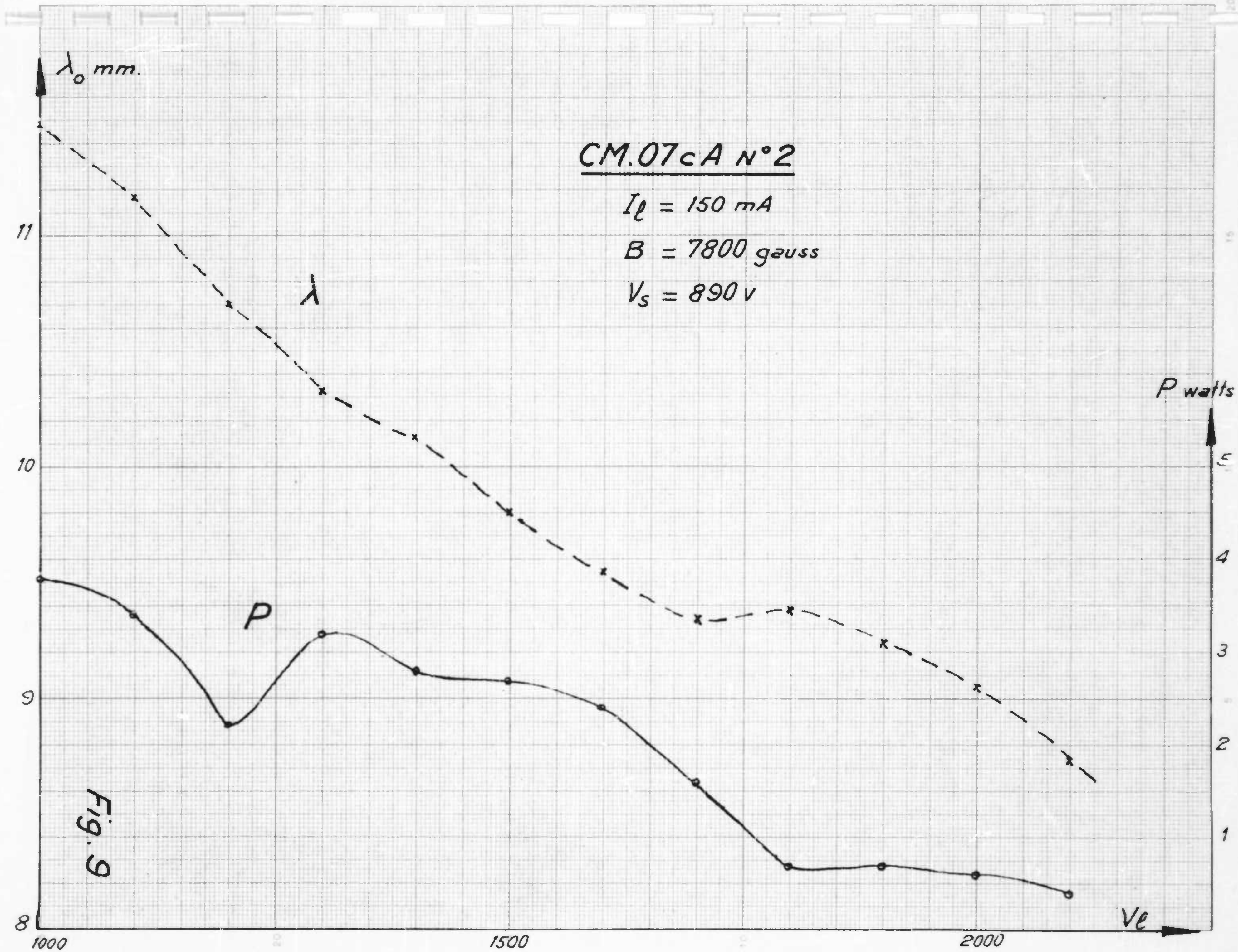

P
CM.07cA N°1
V_ℓ = 1500 v
V_s = 700 v
B = 8040 gauss
Heater { V = 6,4 v ; I = 2,1 A }
4
3
2
1
0
50
100
150
I_ℓ mA
LES PAPIERS CANSON France

Fig. 7



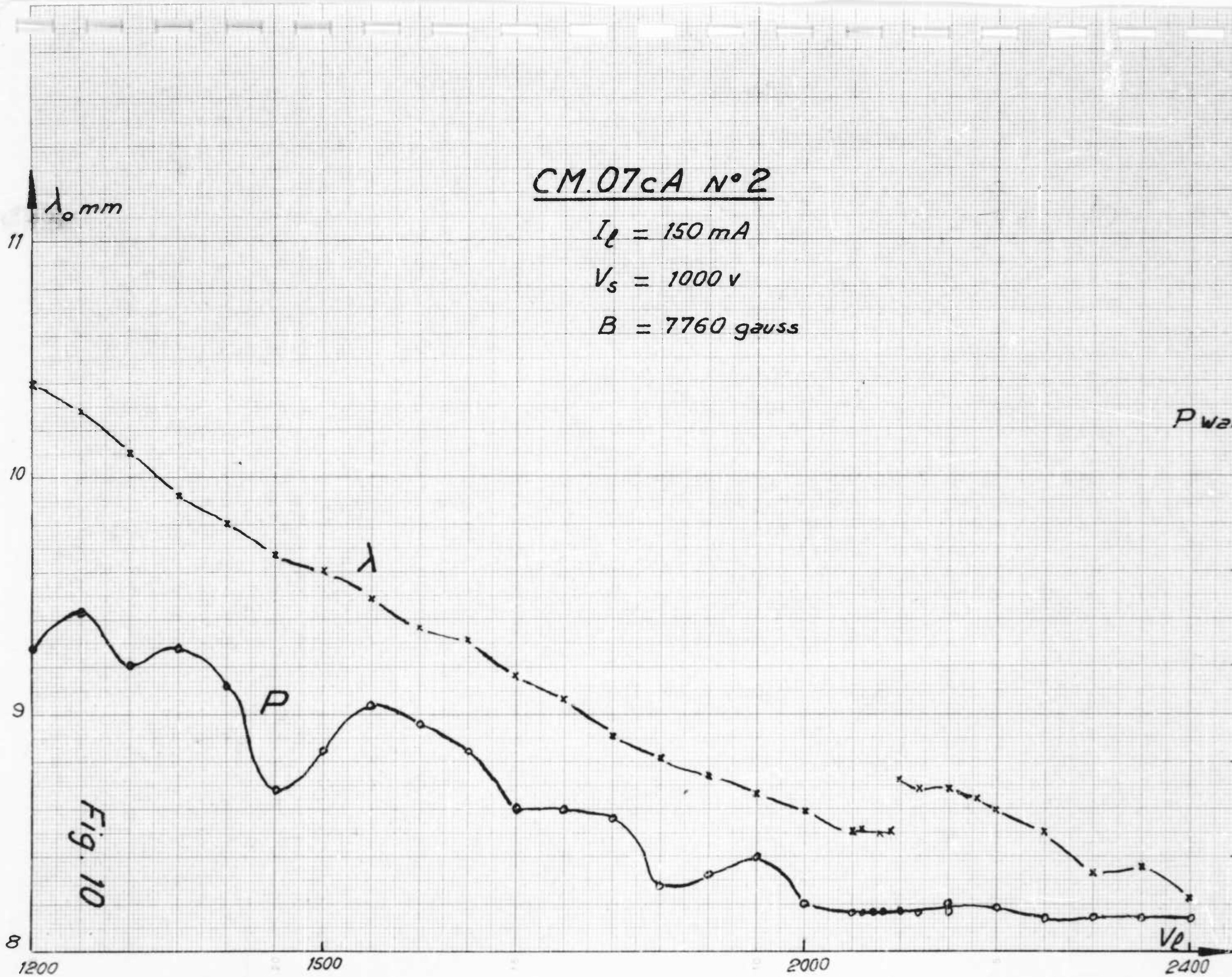
Vp
600
500
400
300
CM.07 c A N°1
Vl = 1500 v
Vs = 720 v
IB = 3,2 A
B = 8040 gauss
Vch = 6 v
λo mm
P watts
9,6
9,5
9,4
λ
5
4
3
2
1
P
I mA
50
100
150

Fig. 8



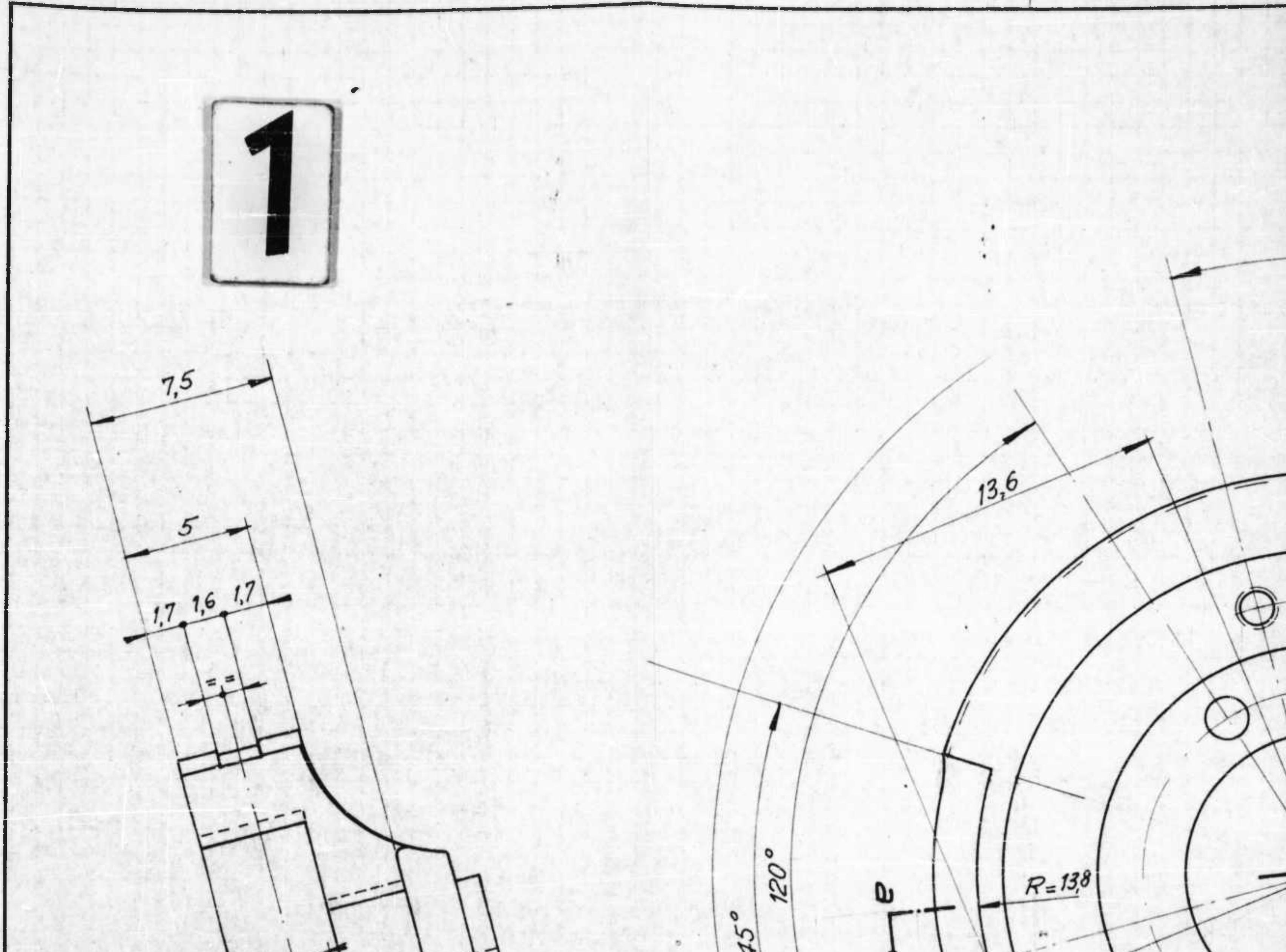
λ_o mm.
CM.07cA N°2
I_ℓ = 150 mA
B = 7800 gauss
V_s = 890 v
λ
P
P watts
V_ℓ
11
10
9
8
1000
1500
2000
5
4
3
2
1

Fig. 9

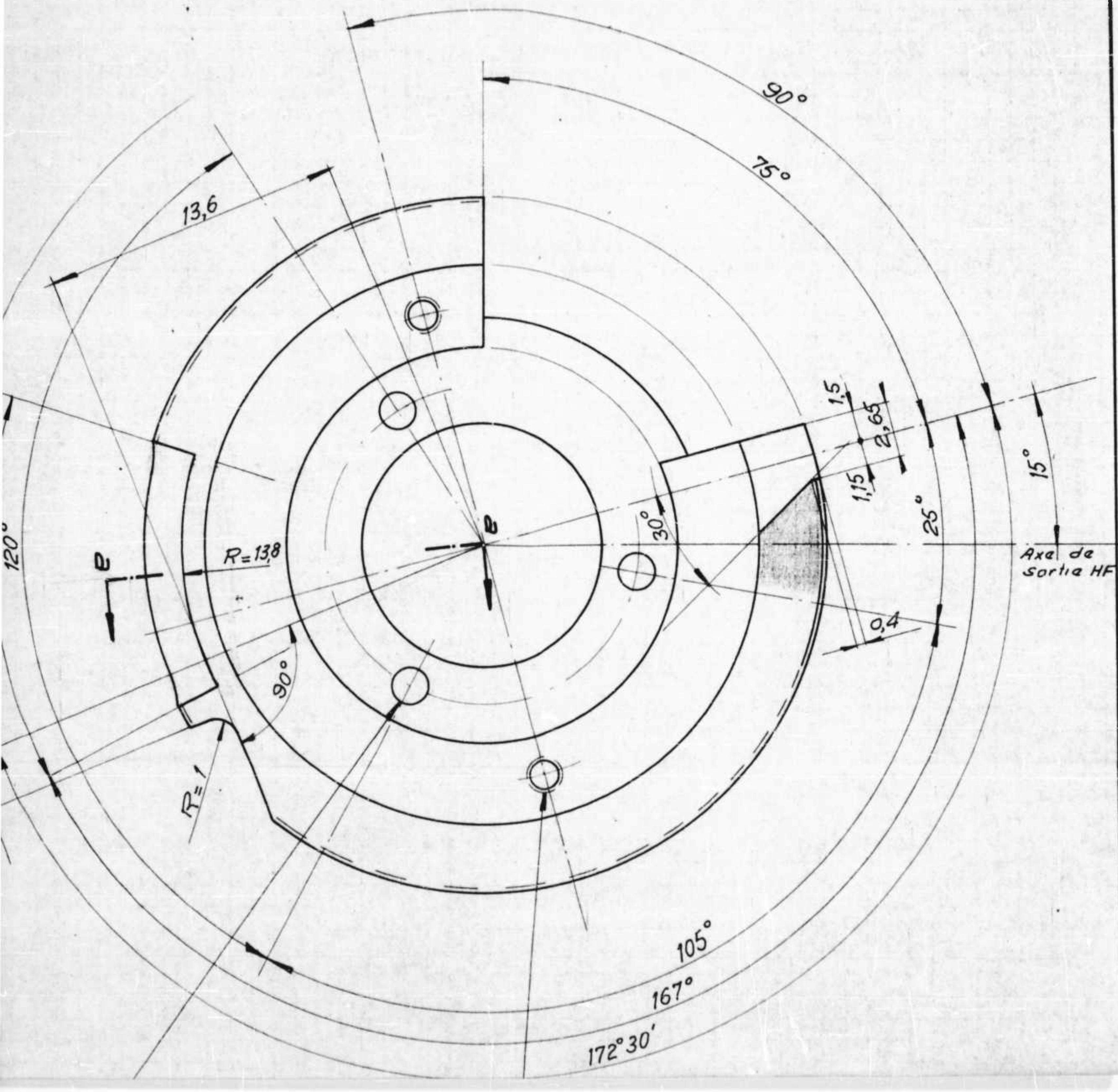


CM.07cA N°2
I_ℓ = 150 mA
V_s = 1000 v
B = 7760 gauss
λ_o mm
11
10
9
8
P watts
5
4
3
2
1
λ
P
1200
1500
2000
2400
V_ℓ

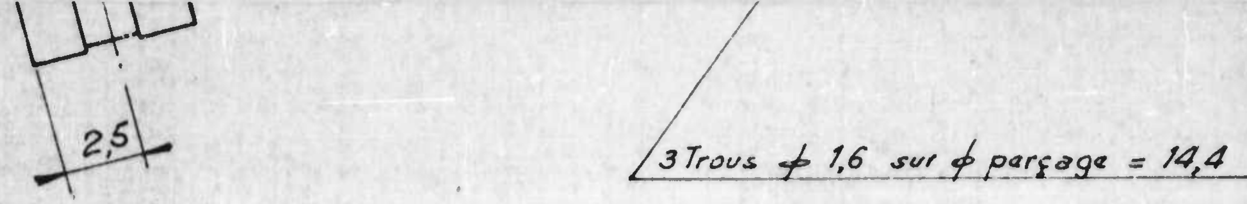
Fig. 10


1
7,5
5
1,7
1,6
1,7
3,3
13,6
120°
45°
R=13,8
90°
R=1
2,6

2

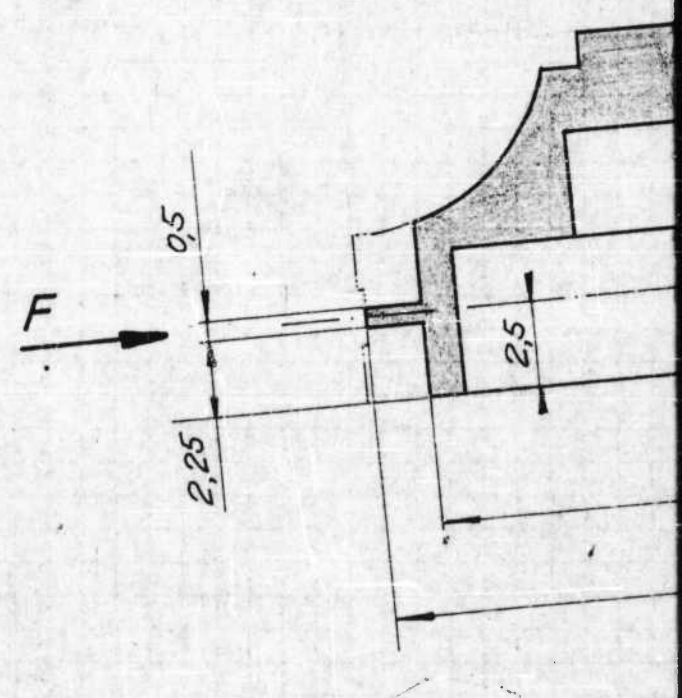


90°
75°
13,6
1,5
2,65
1,15
15°
25°
30°
Axe de
sortie HF
R=13,8
120°
90°
0,4
R=1
105°
167°
172°30'



3

Coupe aa



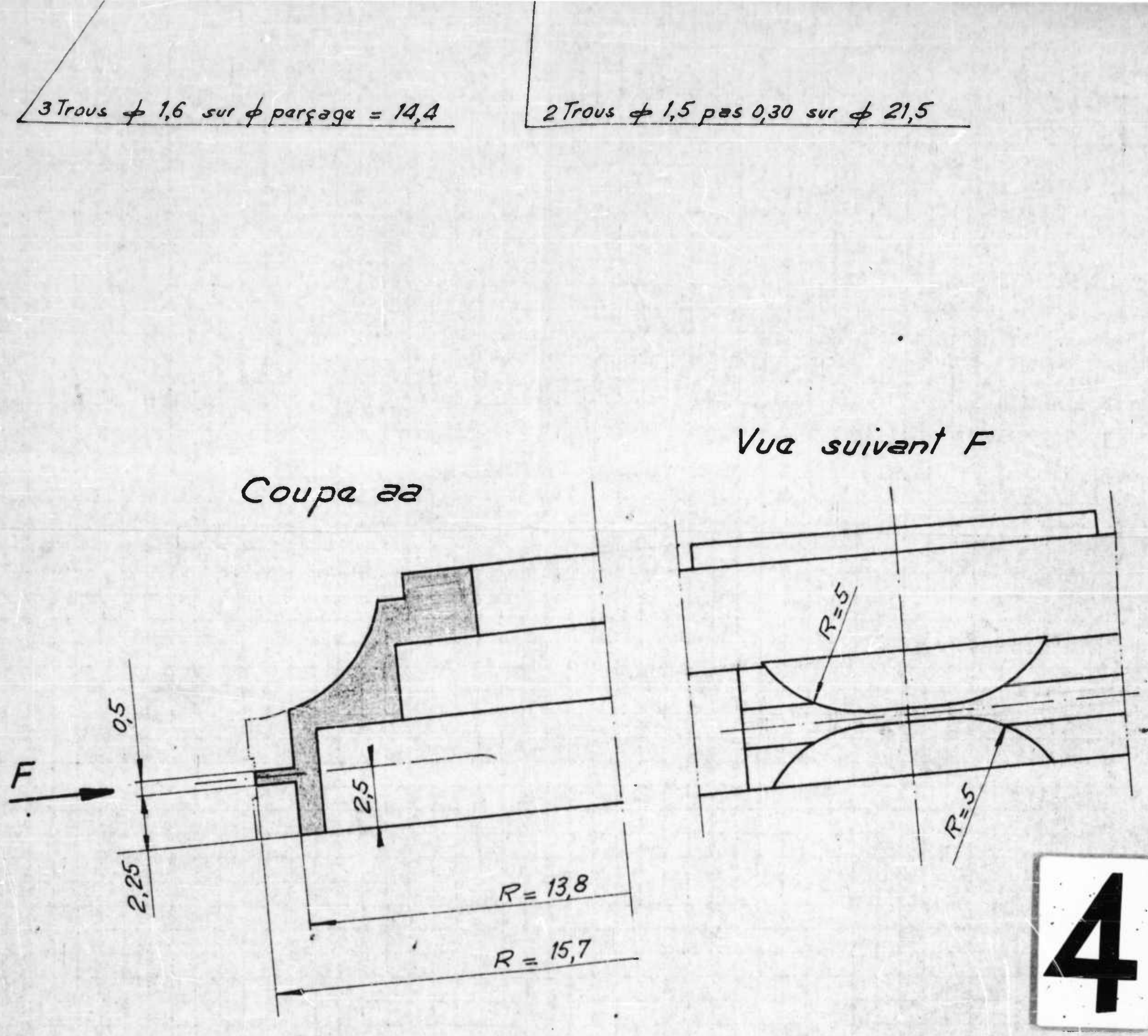
	1		Moly	Ebauche GT. 1009.
REPERE	QUANTITE PAR APPAREIL	DESIGNATION	MATIERE	OBSERVATIONS

ECHELLE :	DATE :	DESSINE PAR :	VERIFIE PAR :	LE CHEF DU BUREAU DE DESSIN :
5/1	3.3.61	GAUTHIER		

N°	DATE	MO

Sol

505 - C 2



4

N°	DATE	MODIFICATION	VISA

DOSSIERS : CM07c.B.

…iche GT. 1009.

OBSERVATIONS

…AU

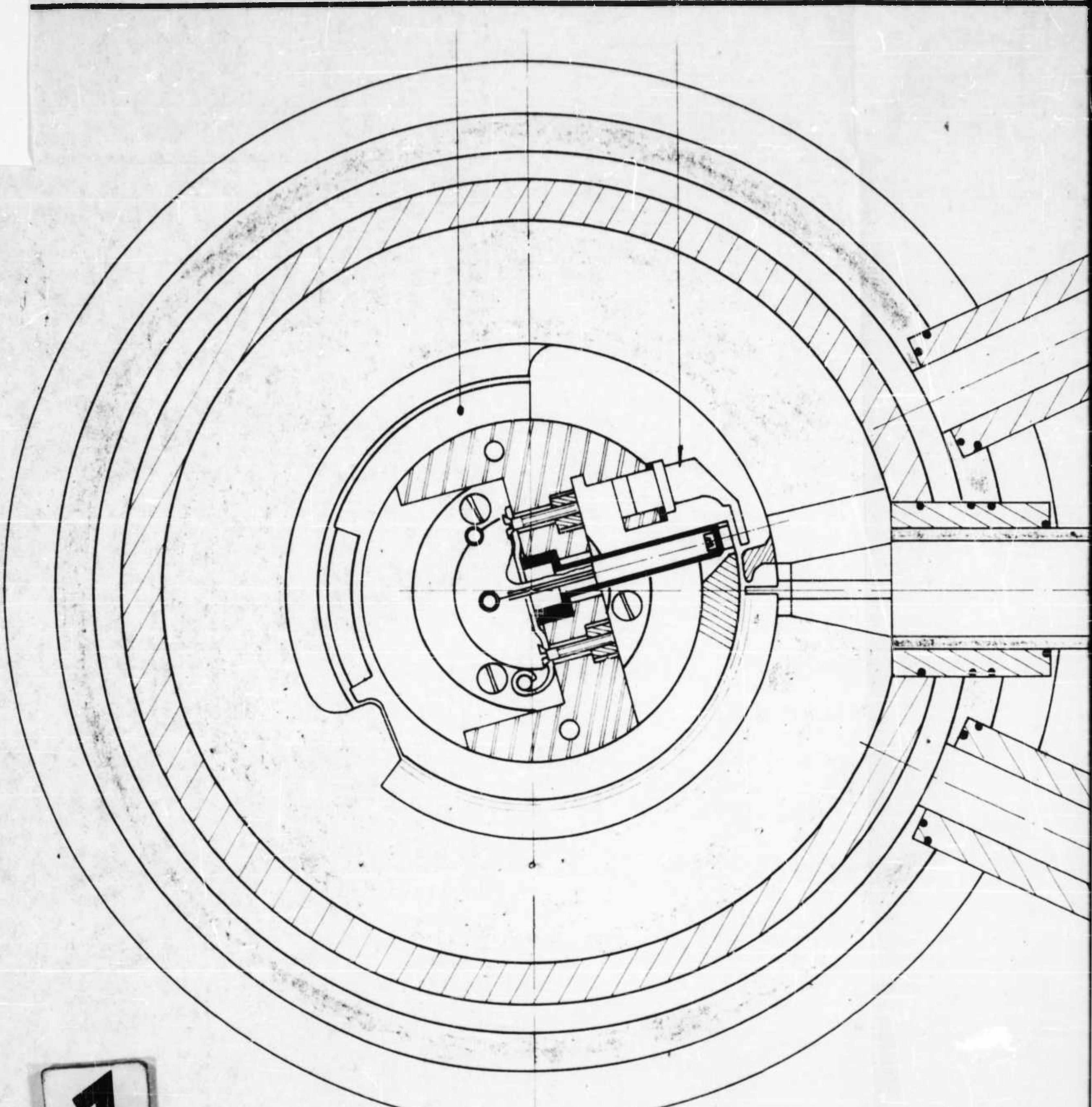
CSF CENTRE DE PHYSIQUE ÉLECTRONIQUE ET CORPUSCULAIRE

Sole finie.

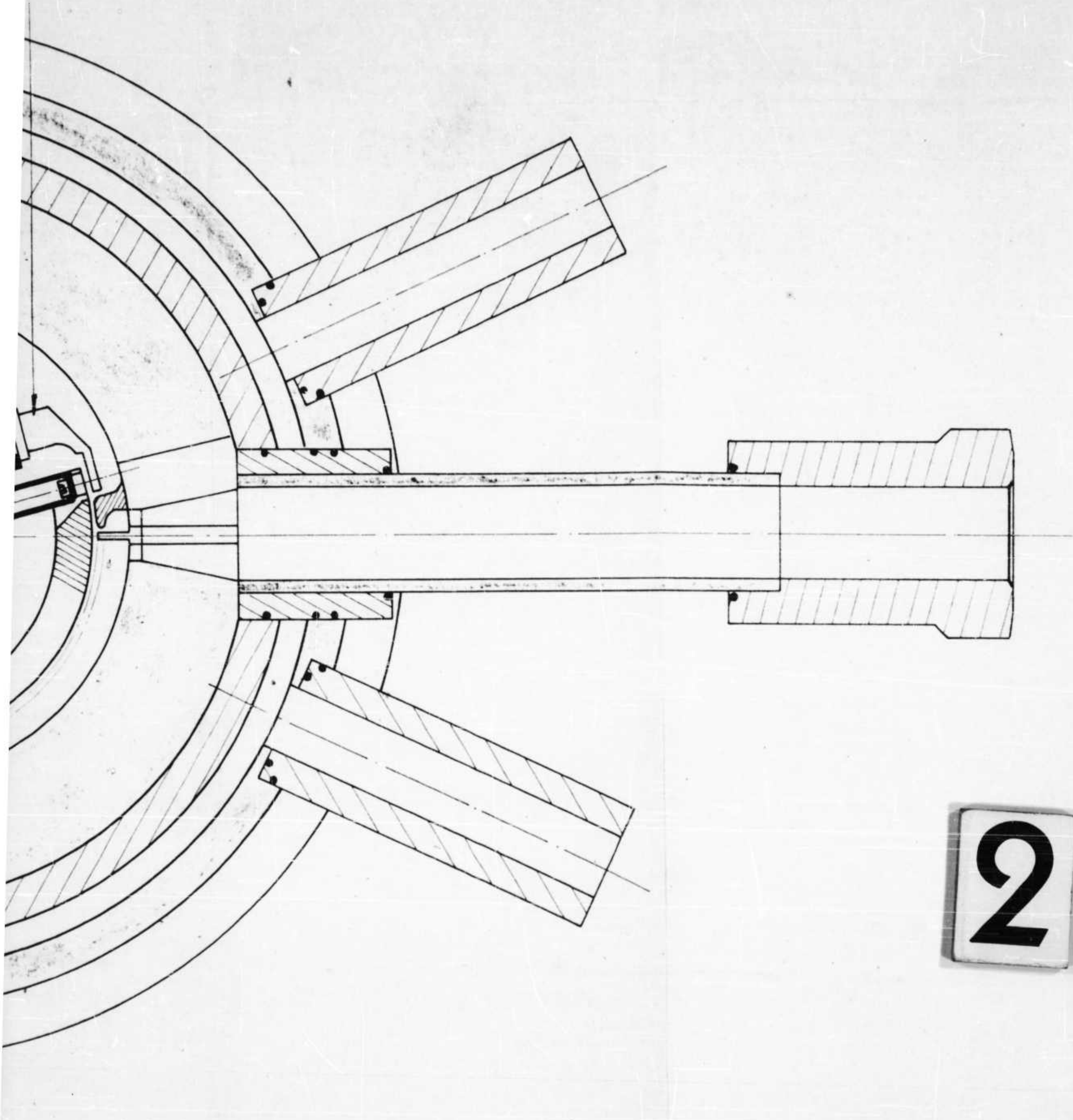
C. Fig. 11

PHOTOGAY-LYON

GT. 1232

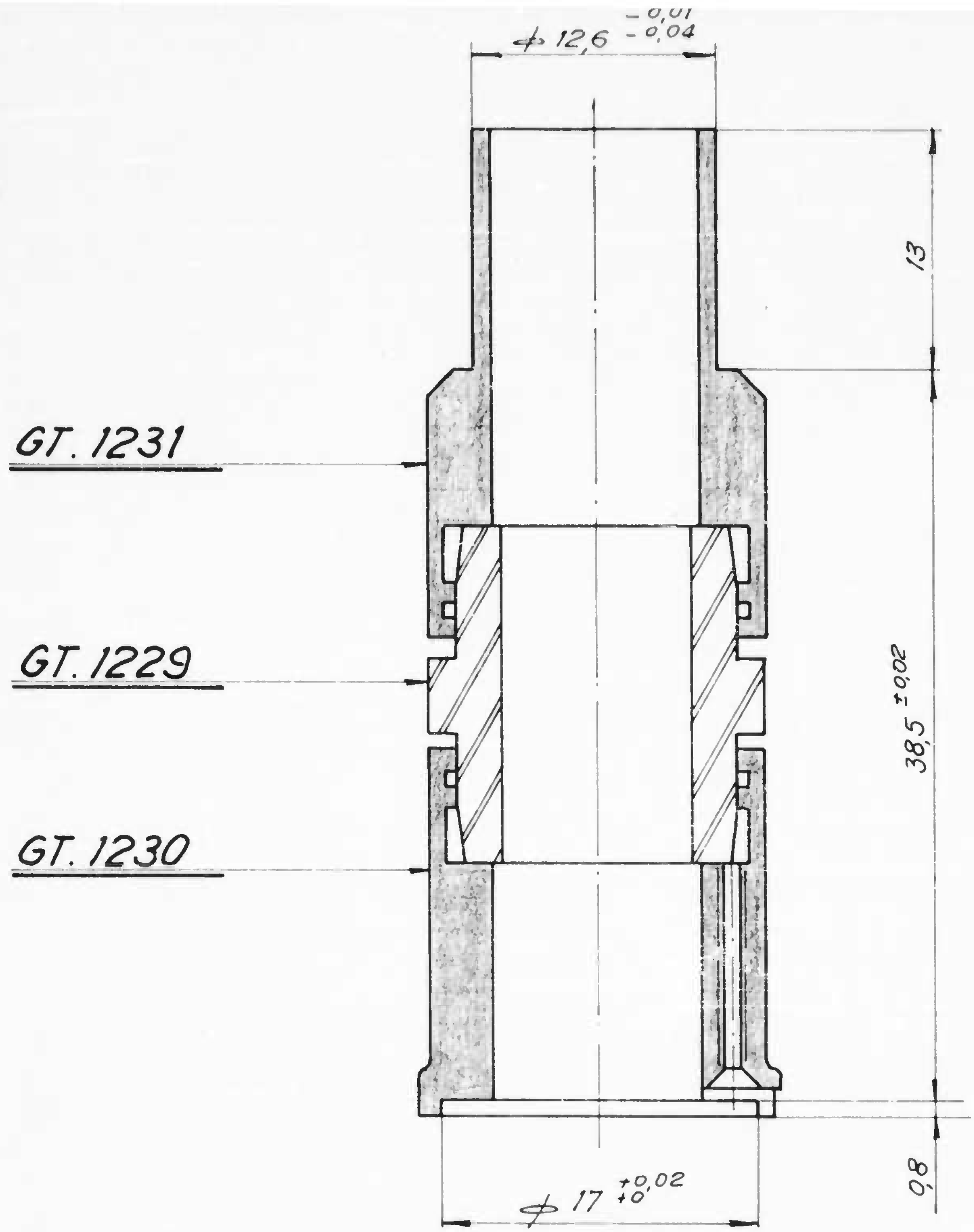


1



2

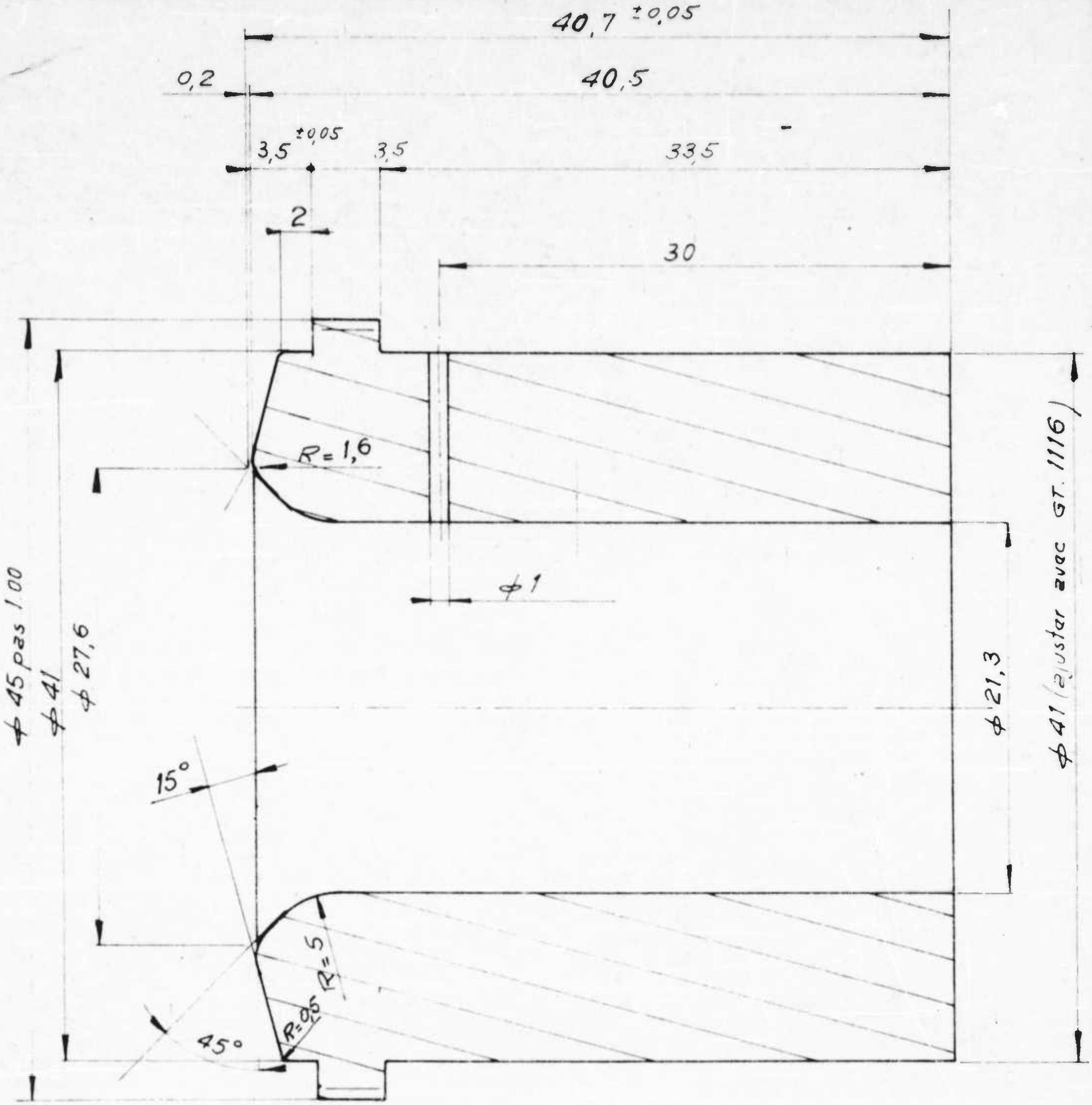
Fig. 12



1 ensemble brasé : Ag. Cu. Pd.

Echelle 3/1 GAUTHIER

CSF	DOSSIERS : CM.07c.B-	DATE : 7.3.61	Dép' C.E.P.E.C.	GT. 1228
	Support de sole.	Fig. 13		

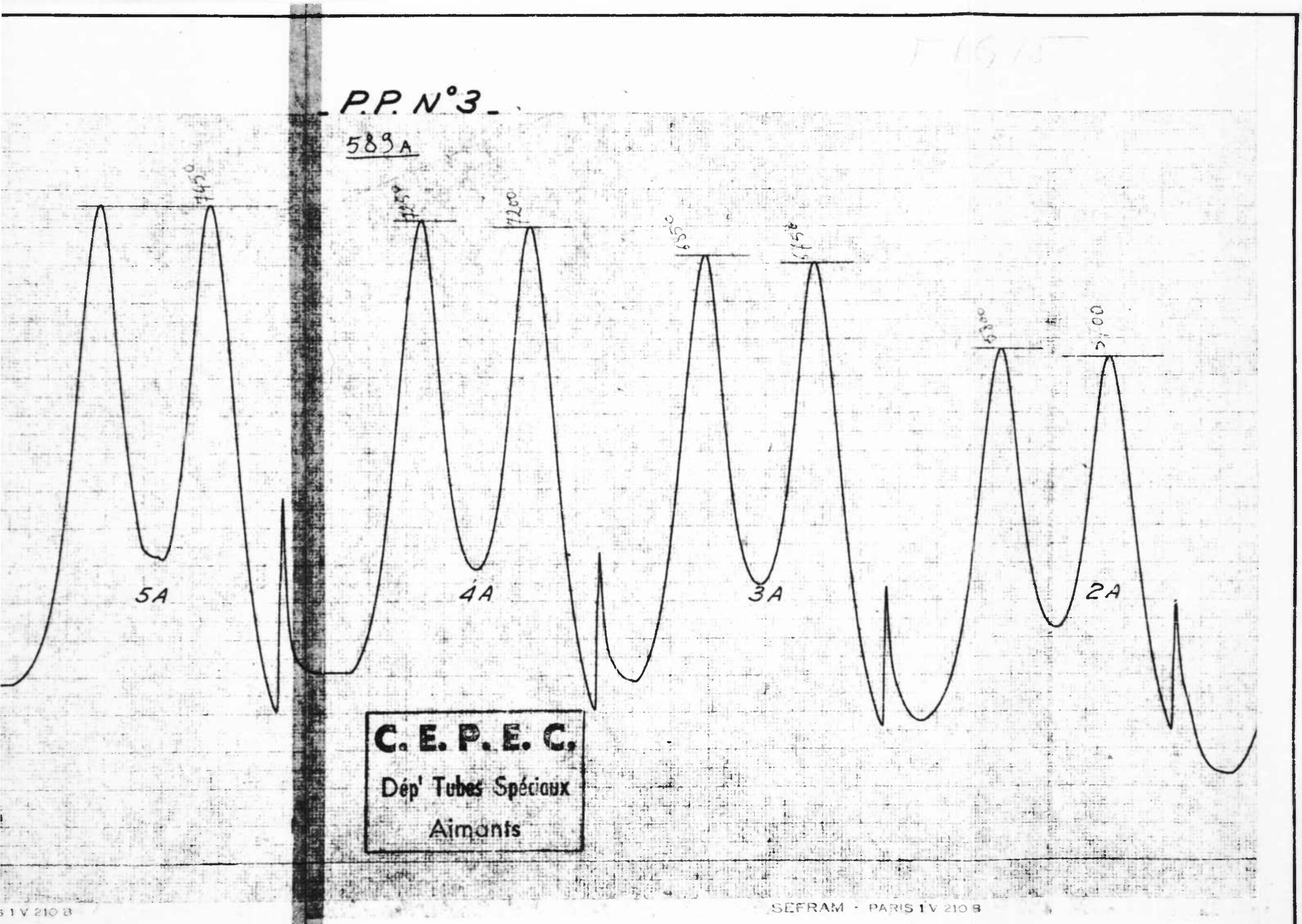


1 pièce : XC.10

Cuivré

P.P. N°3 _ Gap. 8mm.

Fig. 14



_P.P. N°3_
589 A
7450
5A
7250
7200
4A
6550
6750
3A
2A
C. E. P. E. C.
Dép' Tubes Spéciaux
Aimants
SEFRAM - PARIS 1 V 210 B

Fig. 15

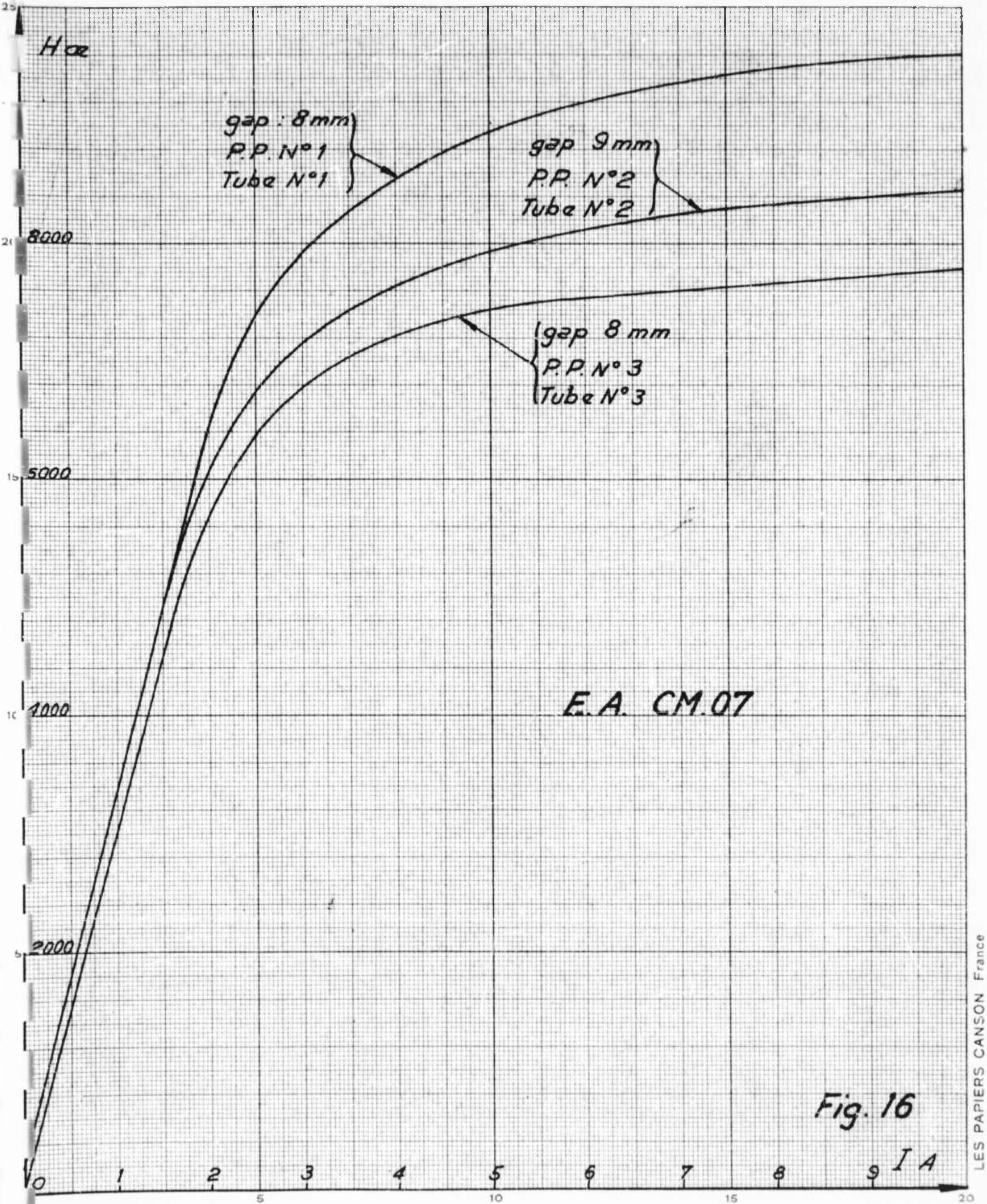

H oe
8000
5000
4000
2000
gap : 8 mm
P.P. N° 1
Tube N° 1
gap 9 mm
P.P. N° 2
Tube N° 2
gap 8 mm
P.P. N° 3
Tube N° 3
E.A. CM.07
0
1
2
3
4
5
6
7
8
9
I A
LES PAPIERS CANSON France

Fig. 16

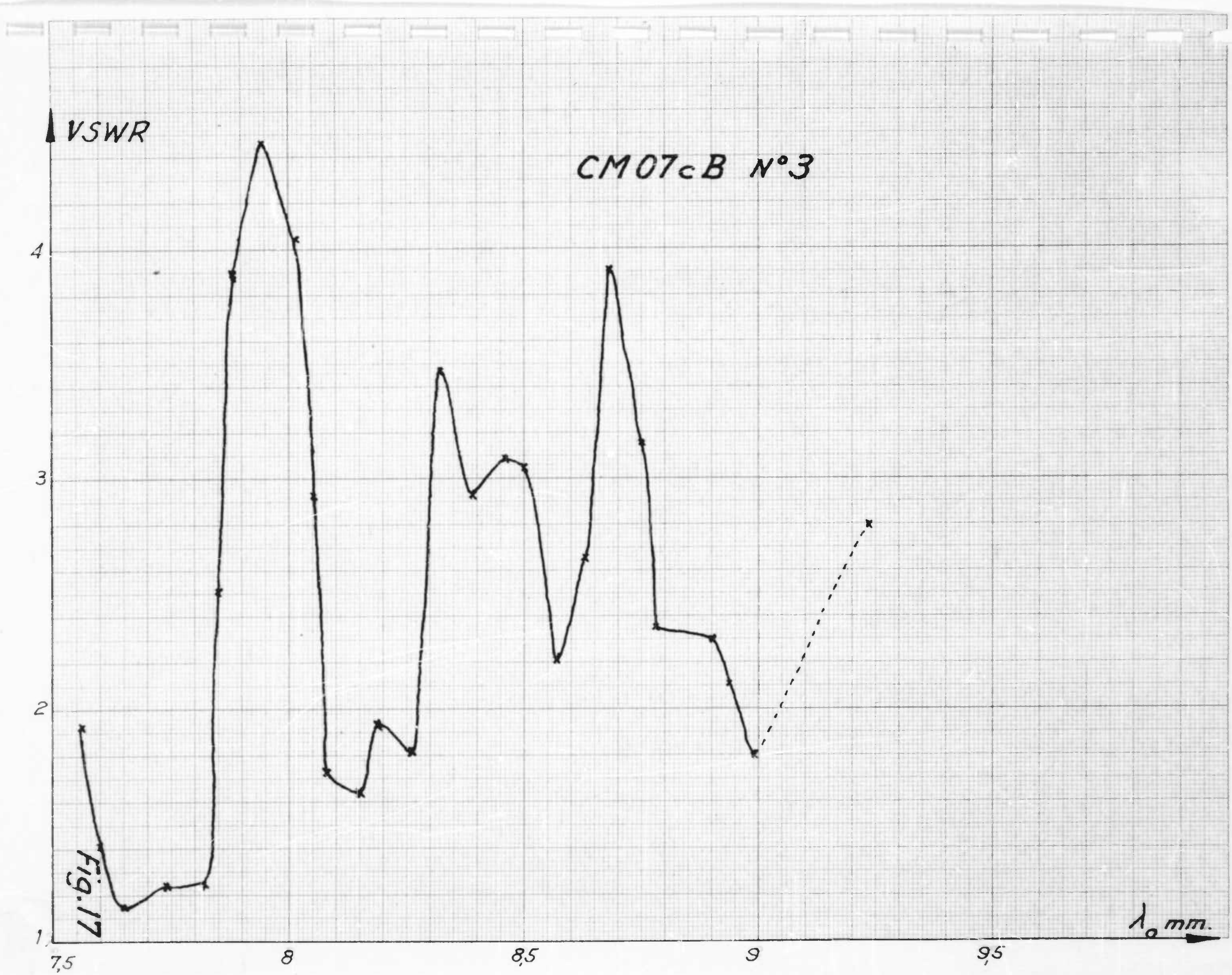


Fig.17

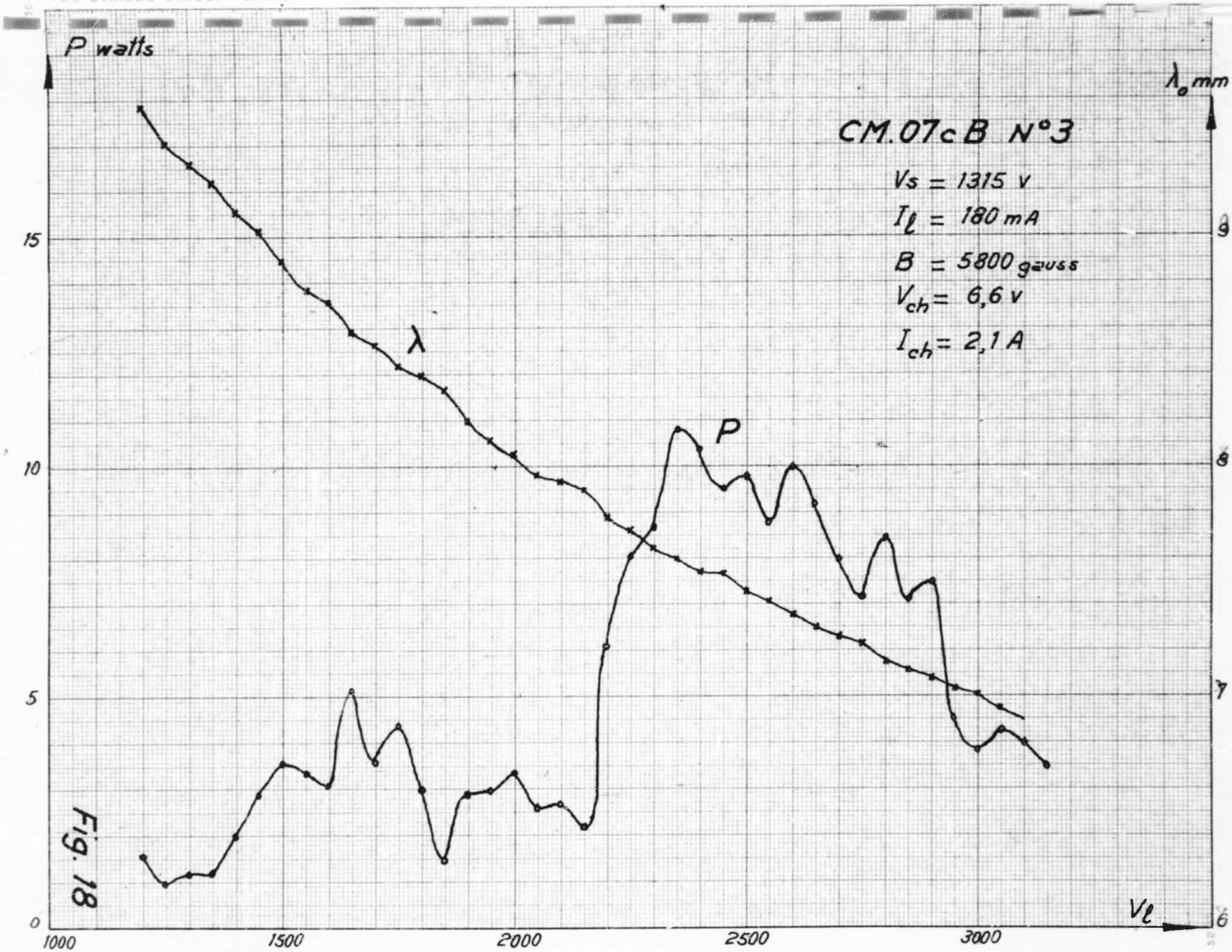
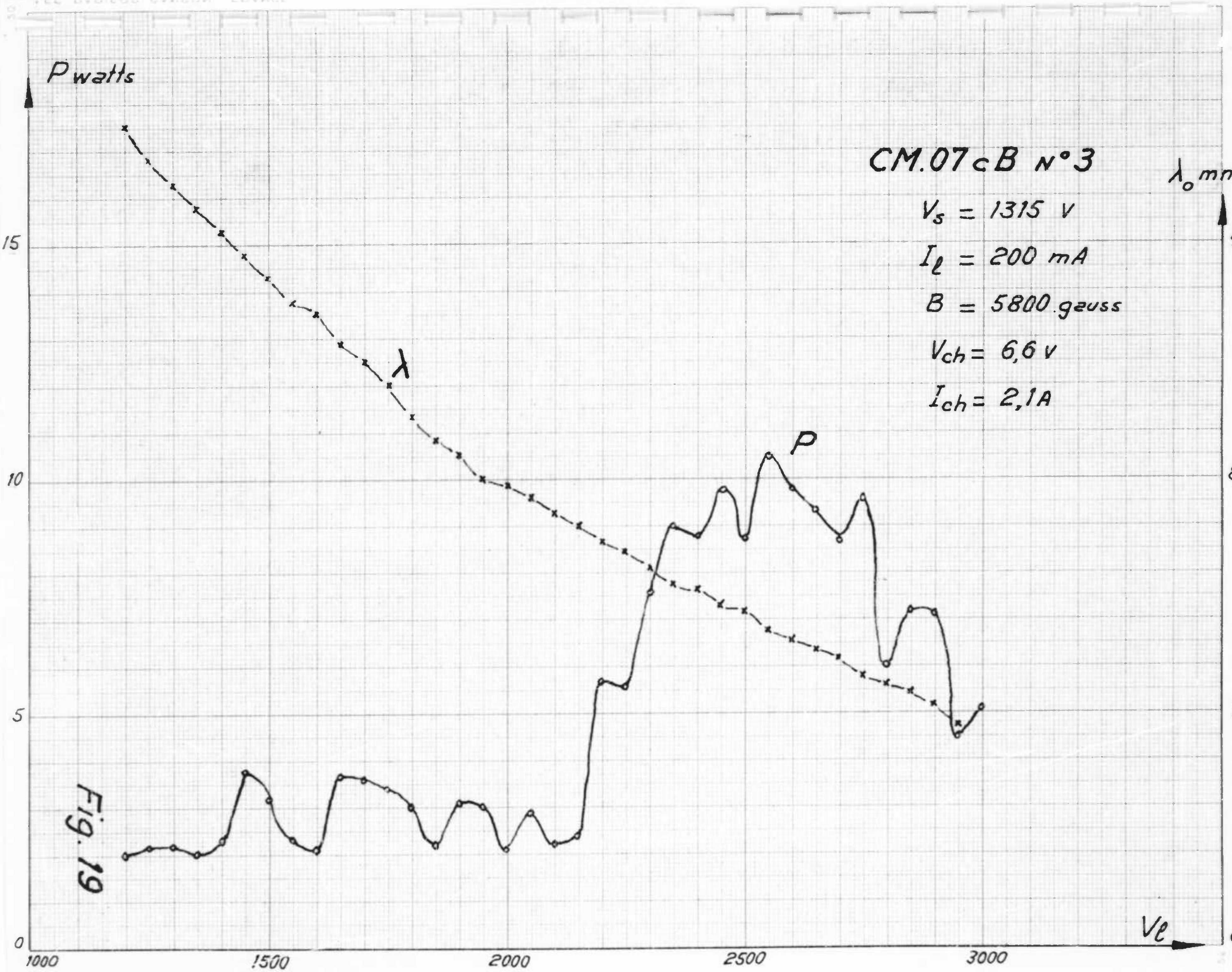
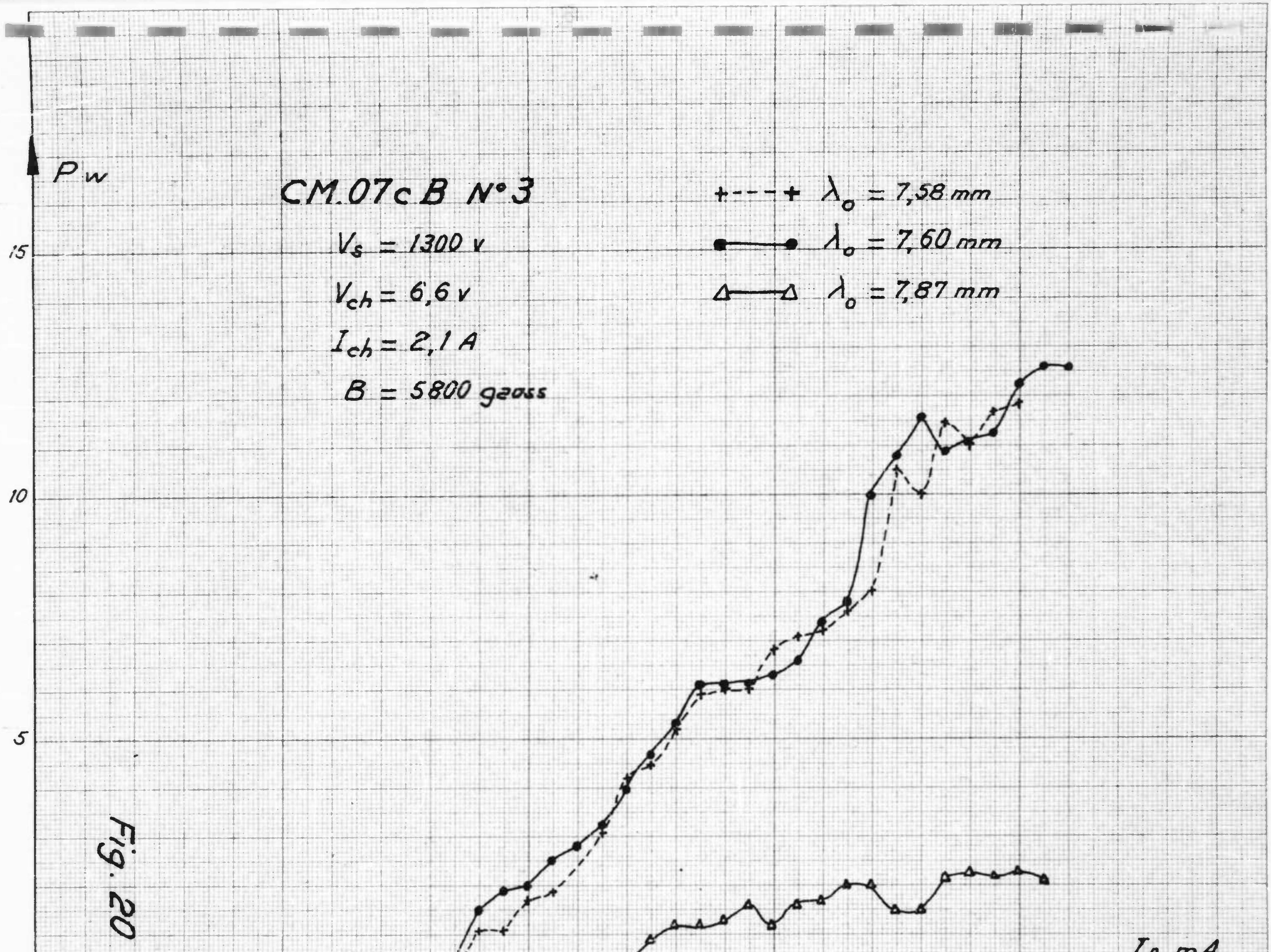

P watts
λ₀ mm
CM.07c B N°3
Vs = 1315 v
Iℓ = 180 mA
B = 5800 gauss
Vch = 6,6 v
Ich = 2,1 A
λ
P
Vℓ
0
5
10
15
6
7
8
9
1000
1500
2000
2500
3000

Fig. 18



P watts
CM.07 cB N°3
V_s = 1315 V
I_ℓ = 200 mA
B = 5800 gauss
V_{ch} = 6,6 V
I_{ch} = 2,1 A
λ_o mm
λ
P
V_ℓ
15
10
5
0
9
8
7
6
1000
1500
2000
2500
3000

Fig. 19


Pw
CM.07c B N°3
V_s = 1300 v
V_{ch} = 6,6 v
I_{ch} = 2,1 A
B = 5800 gauss
λ_o = 7,58 mm
λ_o = 7,60 mm
λ_o = 7,87 mm
I_ℓ mA
0
5
10
15
100
150
200
Fig. 20

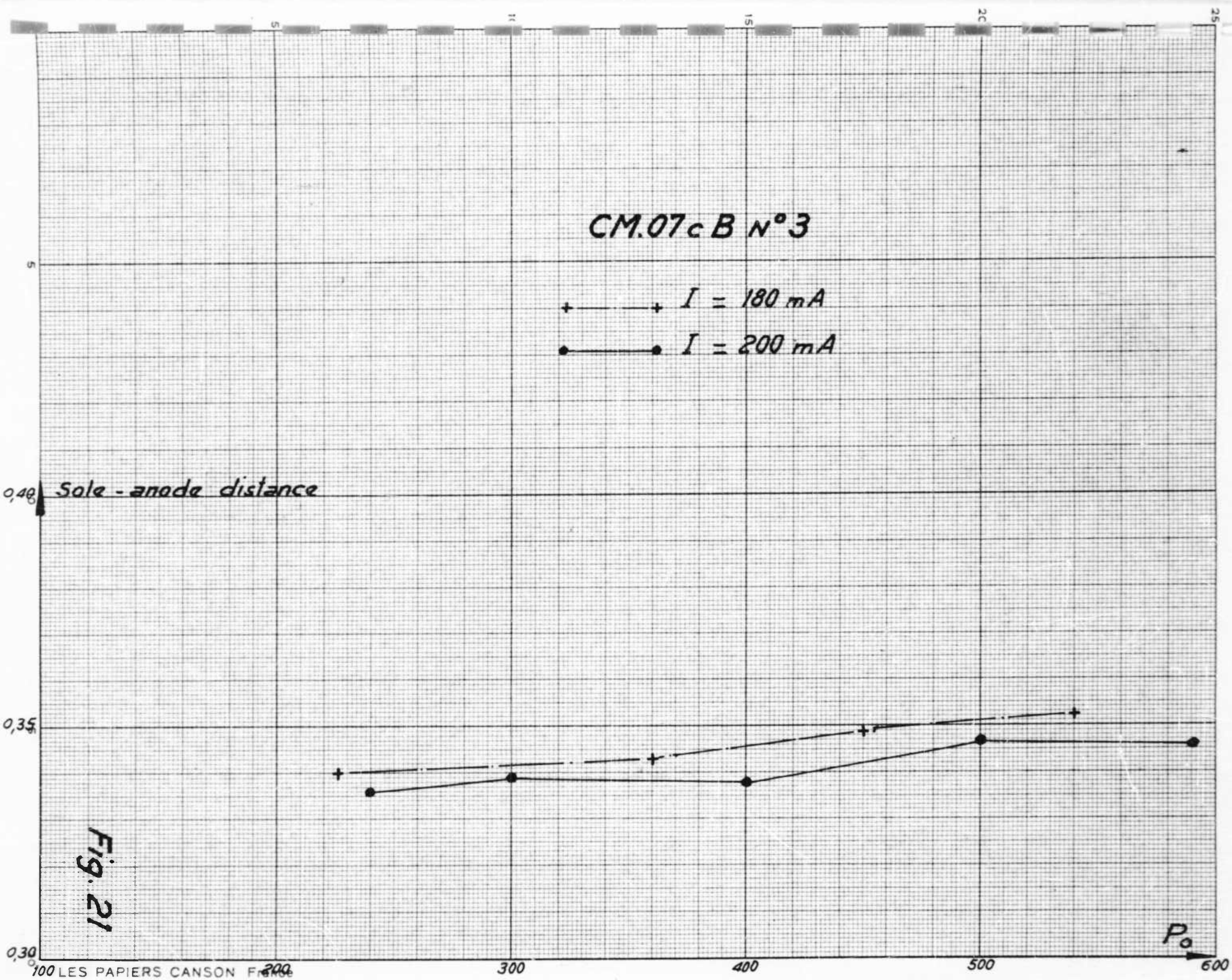
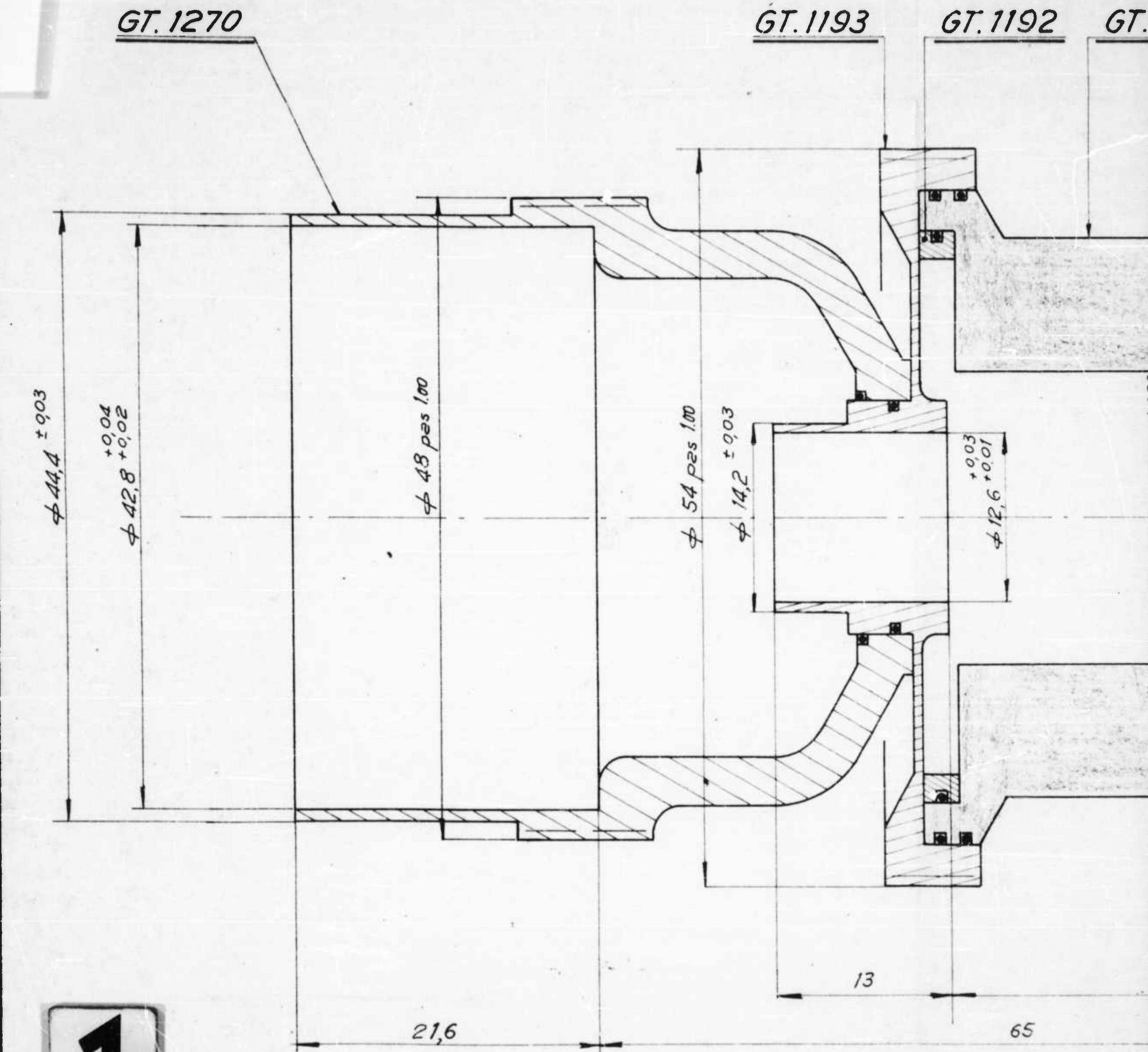

CM.07c B N°3
I = 180 mA
I = 200 mA
Sole - anode distance
0,40
0,35
0,30
100
200
300
400
500
600
P_o
LES PAPIERS CANSON France

Fig. 21



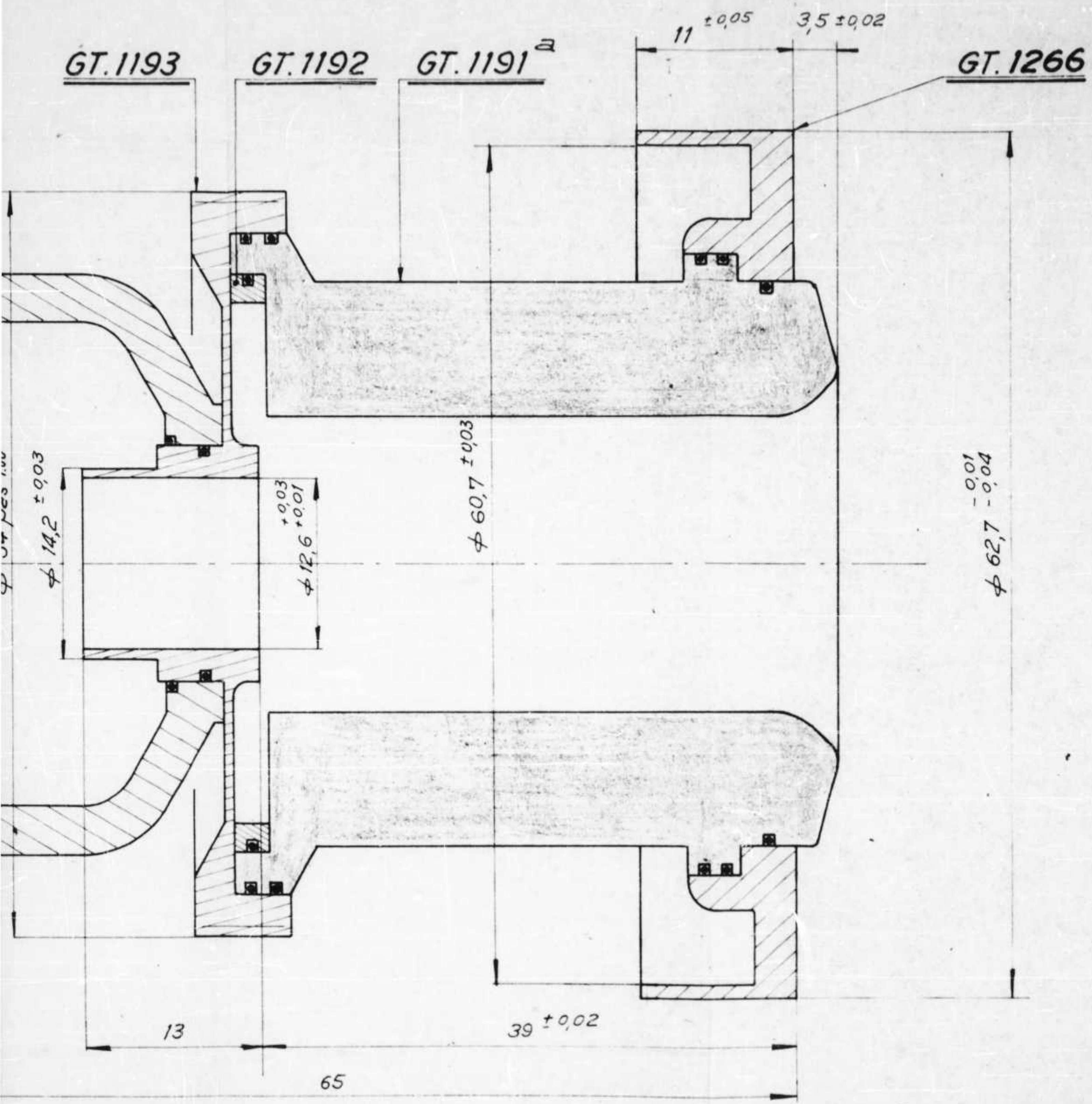
1

1 ensemble brasé
(Ag.Cu).

DOSSIERS

CSF

Couva



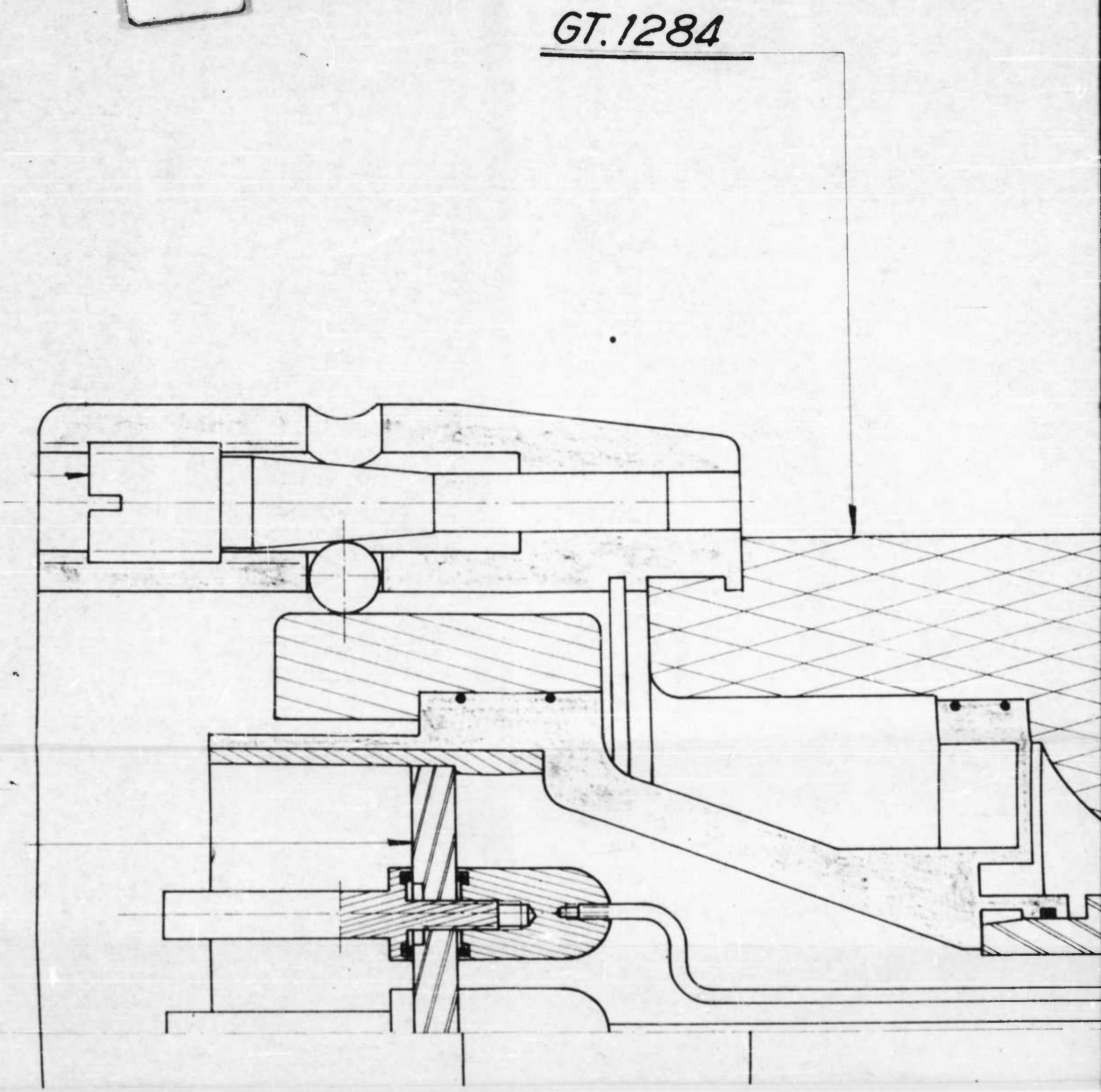
2

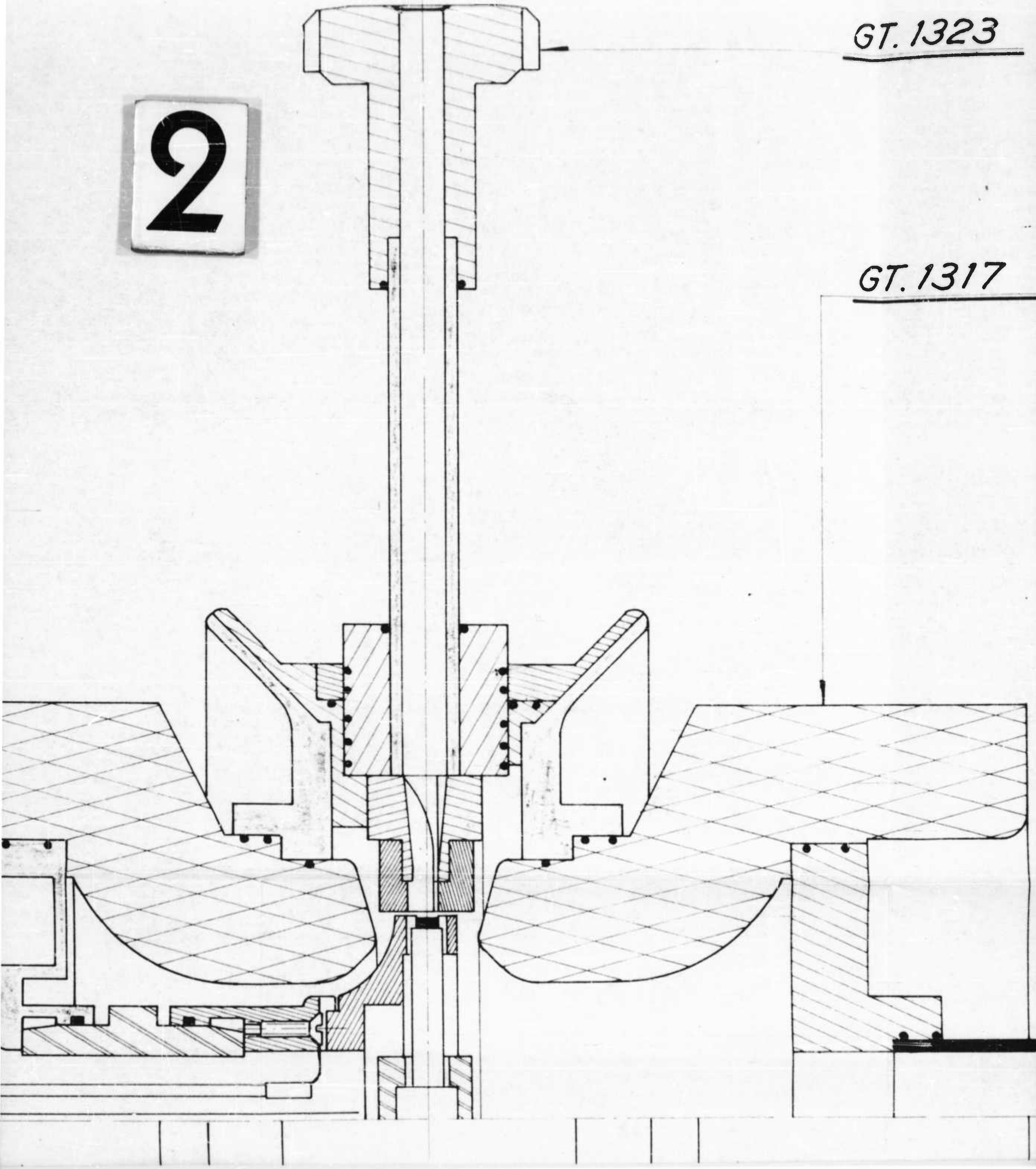
Echelle 3/1

GAUTHIER

CSF	DOSSIERS : CM.07c.C _	DATE 22.3.61	Dep^t C.E.P.E.C.	GT. 1271
	Couvercle supérieur monté.	Fig. 22		

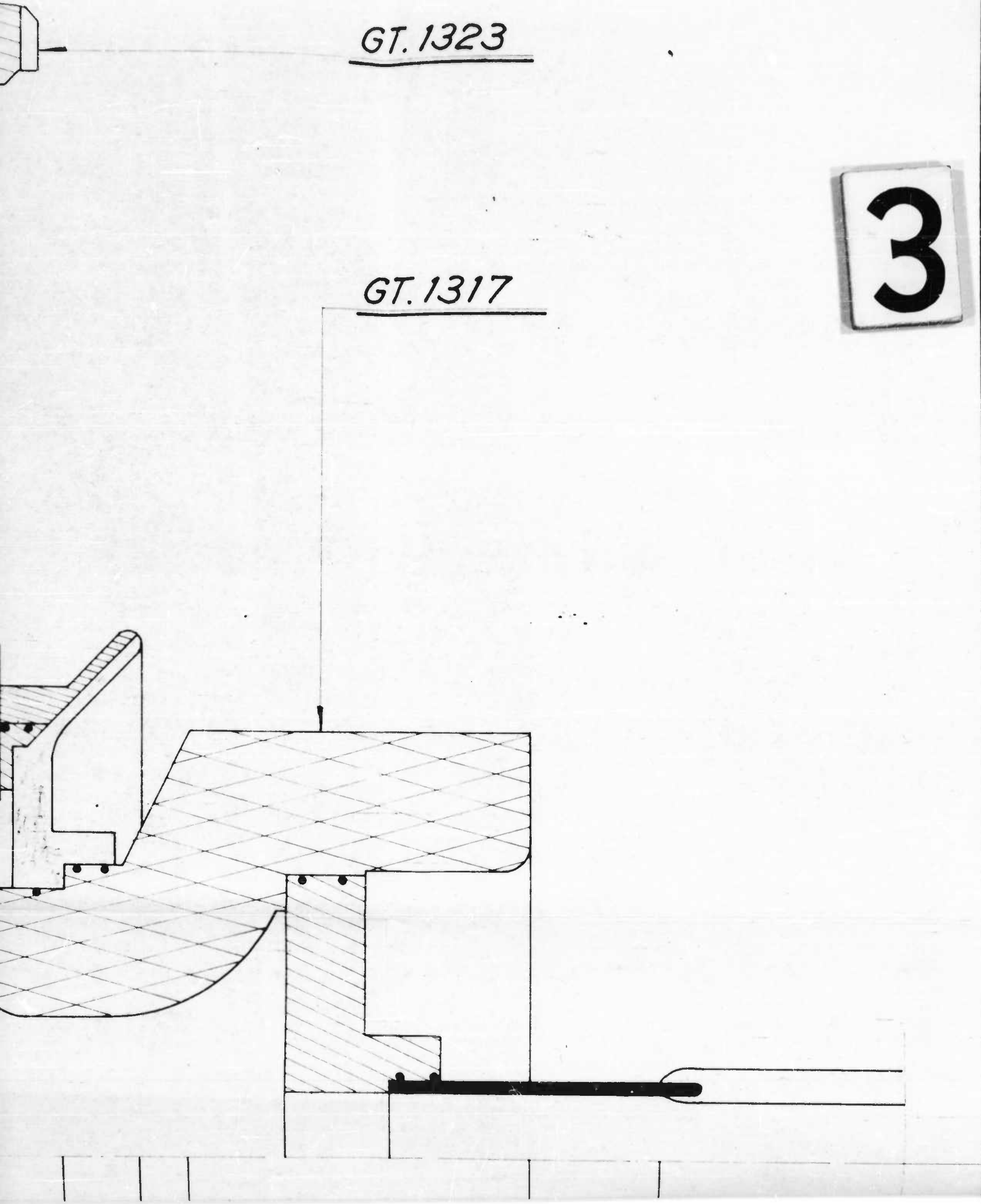
1

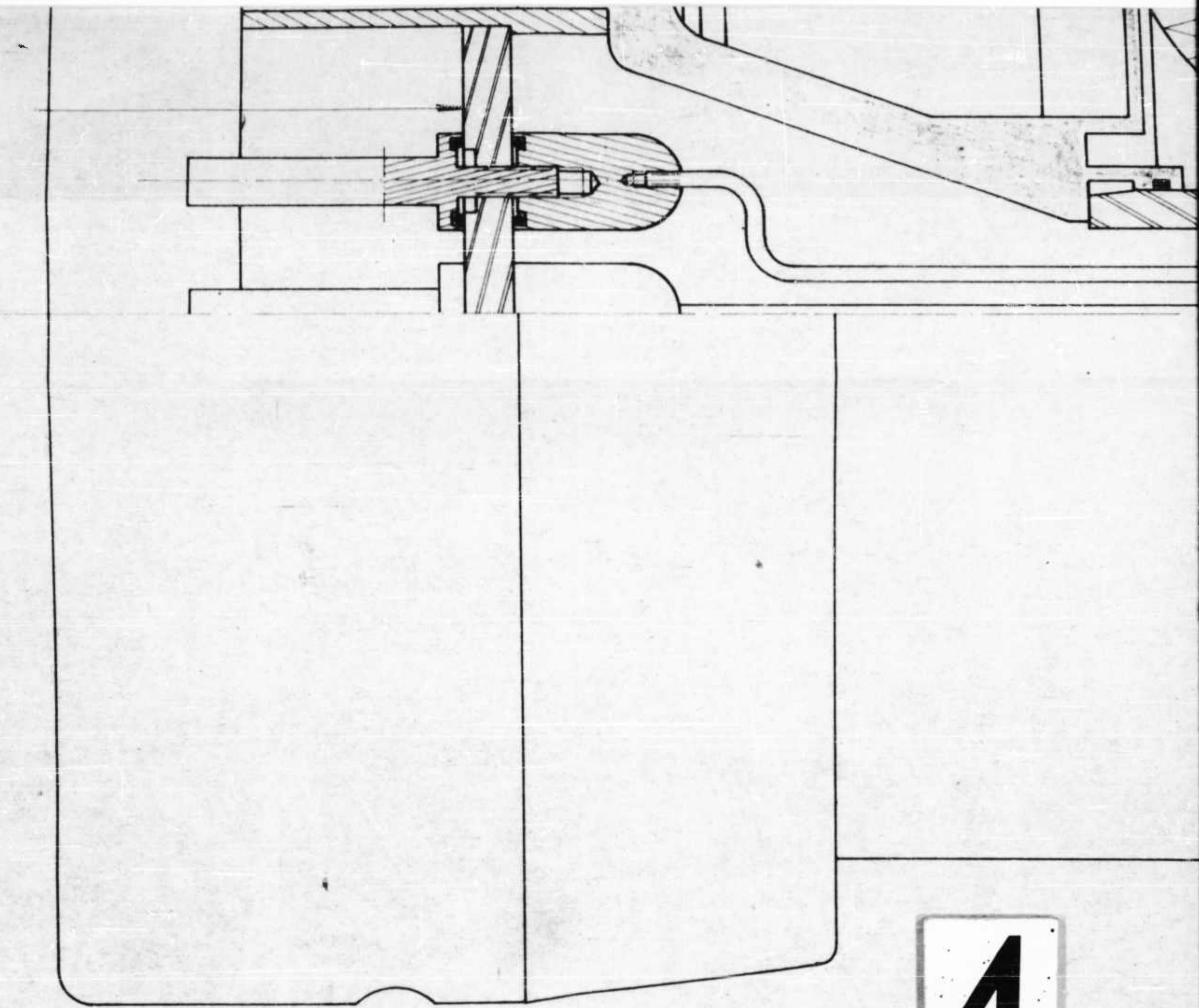




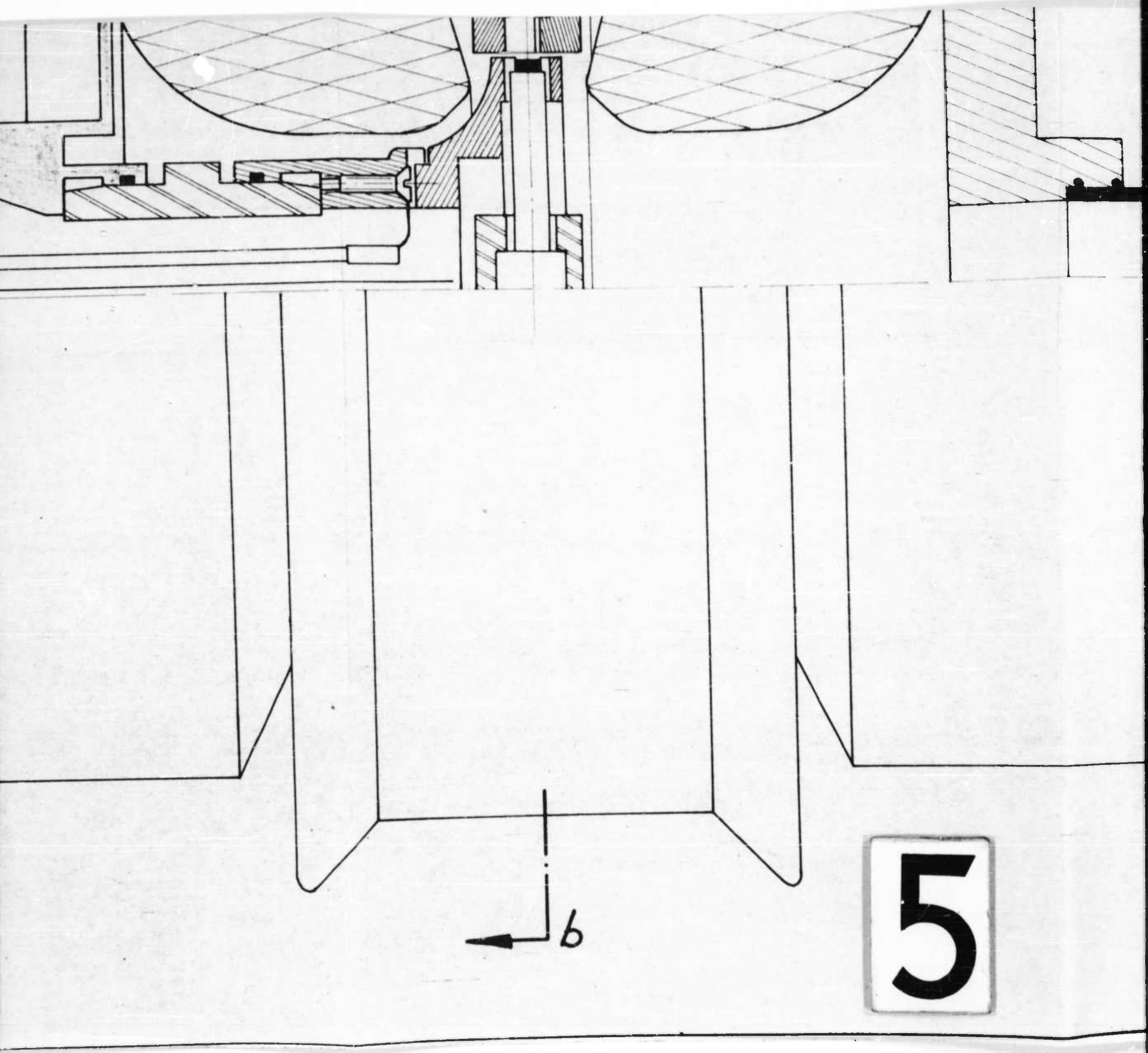
GT. 1323
2
GT. 1317

3





4



5

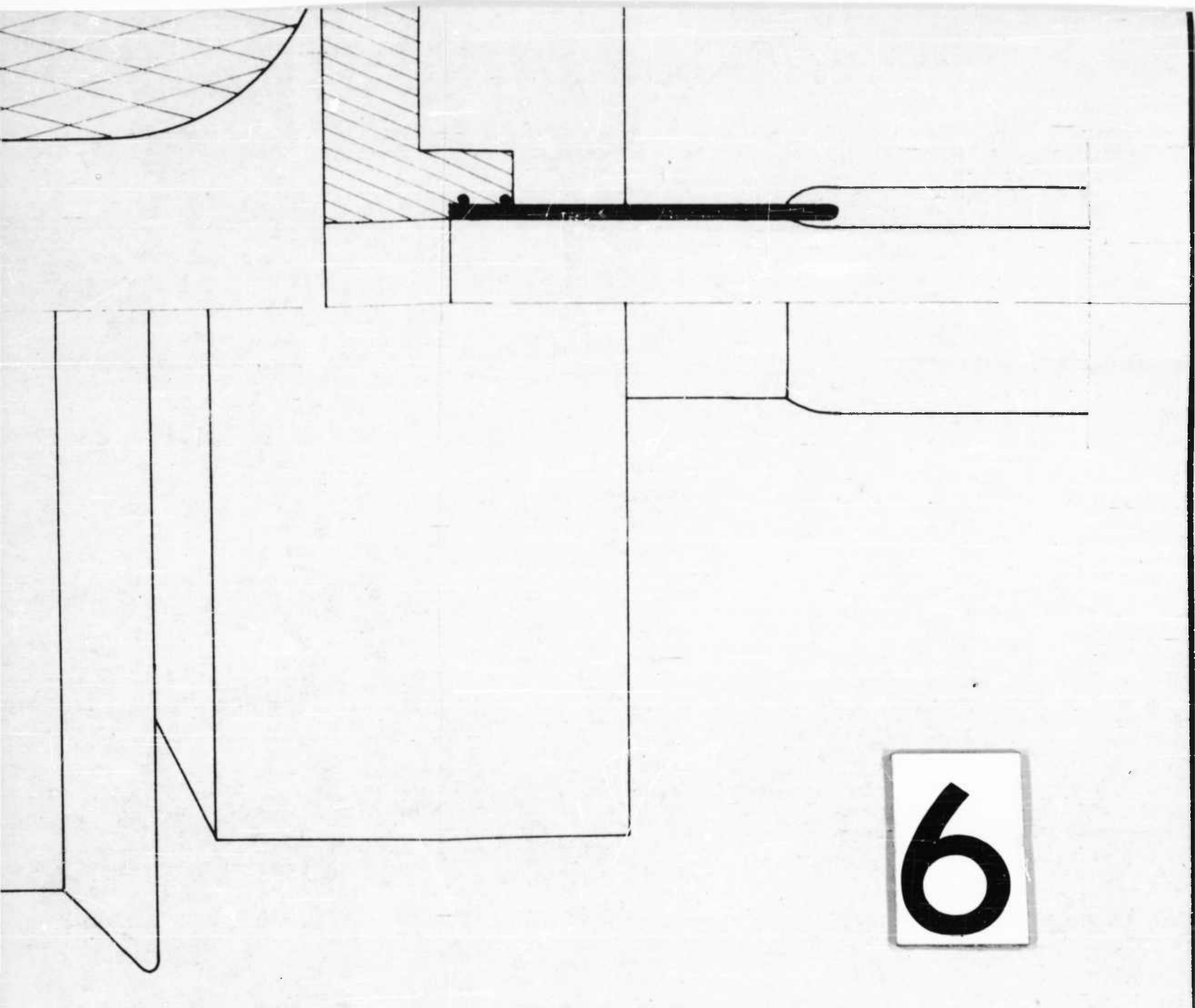
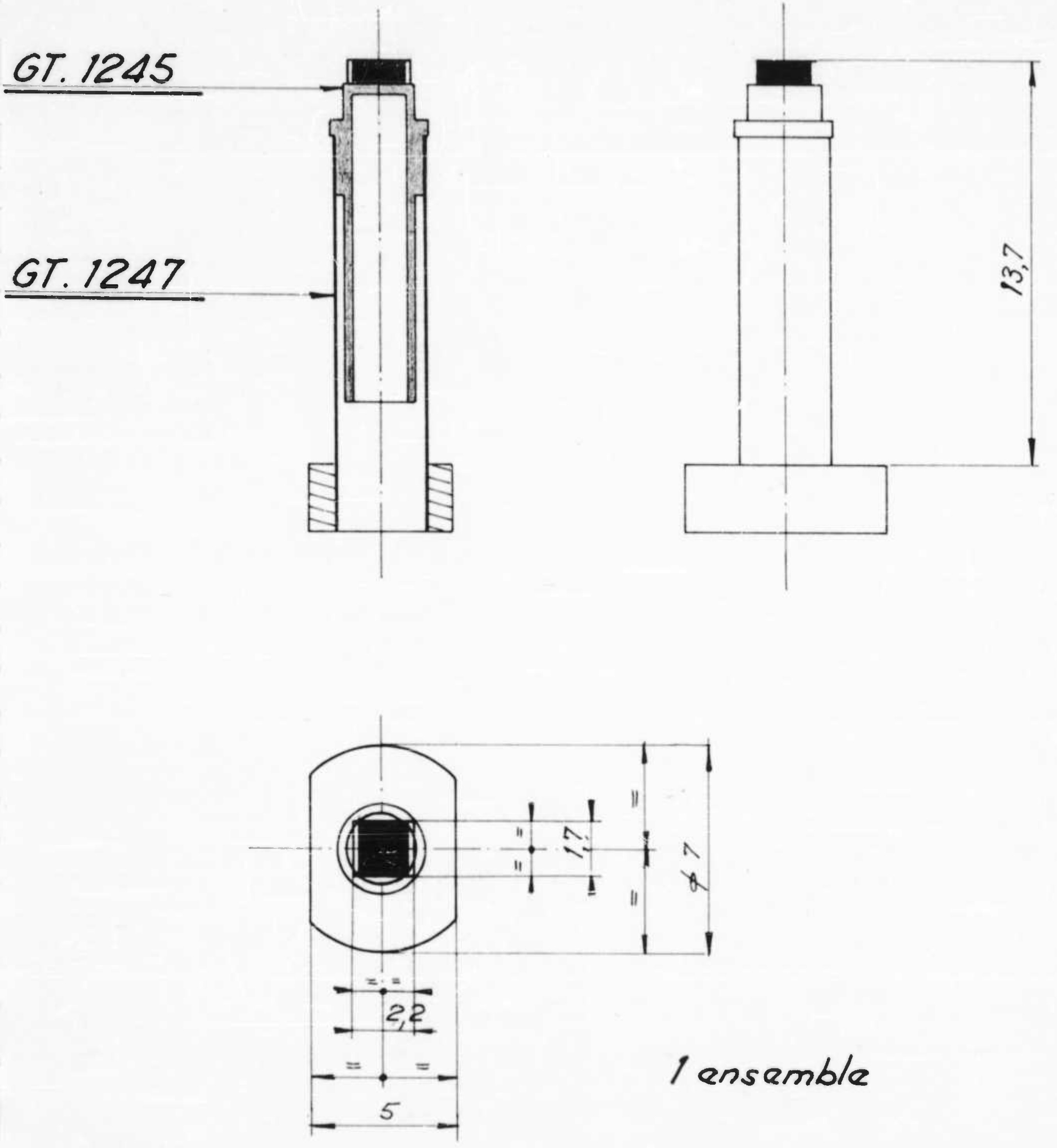


Fig. 23

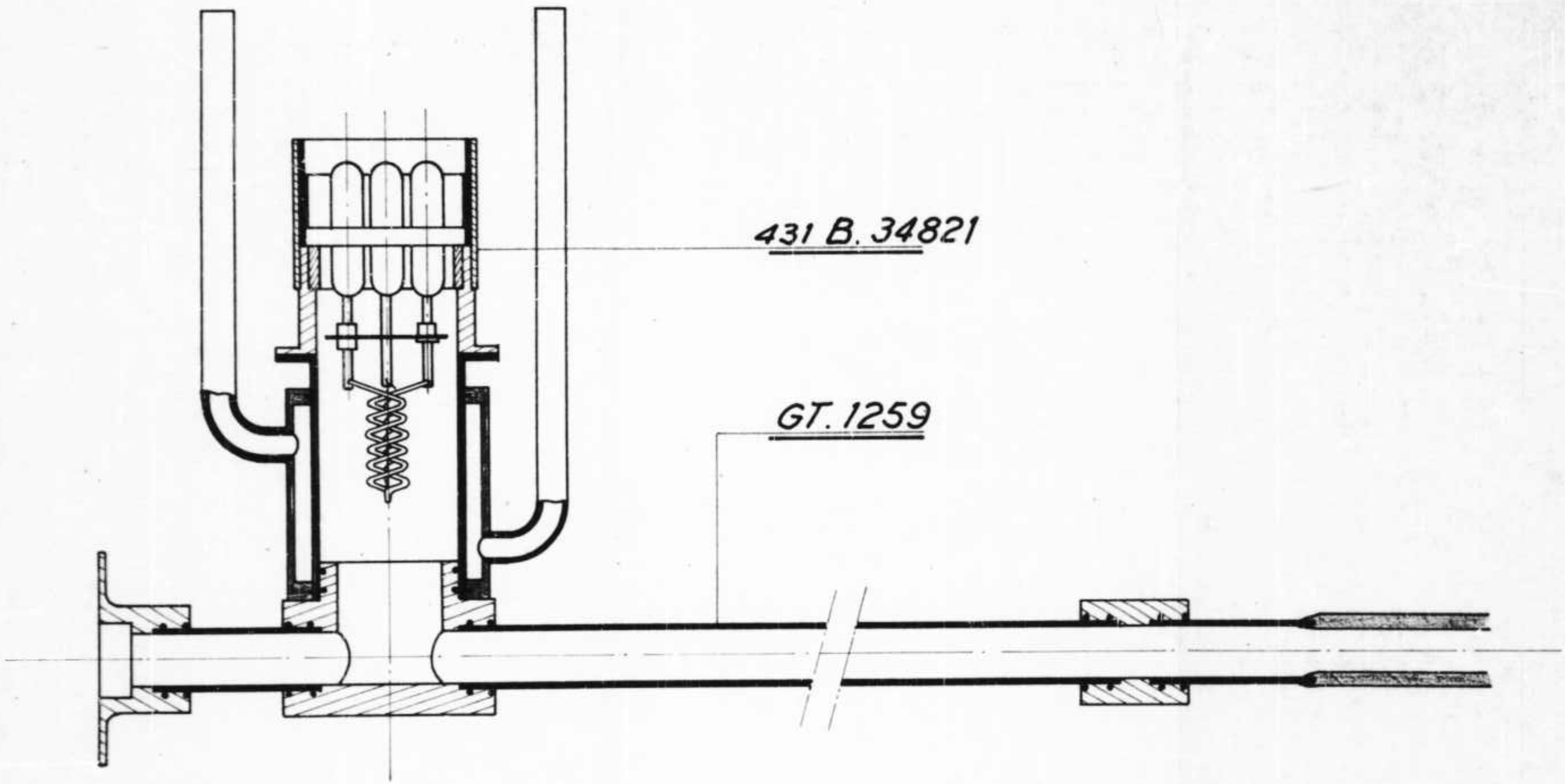


a/le 11.4.61 Modifié position de GT. 1245 par rapport à GT. 1247

Echelle 5/1

GAUTHIER

CSF	DOSSIERS : CM07c	DATE : 8.3.51	Dép^t C.E.P.E.C.	GT. 1244
	Cathode finie	Fig. 24		a



1 ensemble

Echelle 1/1 GAUTHIER

CSF	DOSSIERS : CM 07c.C.	DATE : 15.3.61	Dépt C.E.P.E.C.	GT. 1258
	Pompe titane pour CM 07c C.	Fig. 25		

PHOTOGAY-LYON

DIRECTIONAL COUPLER

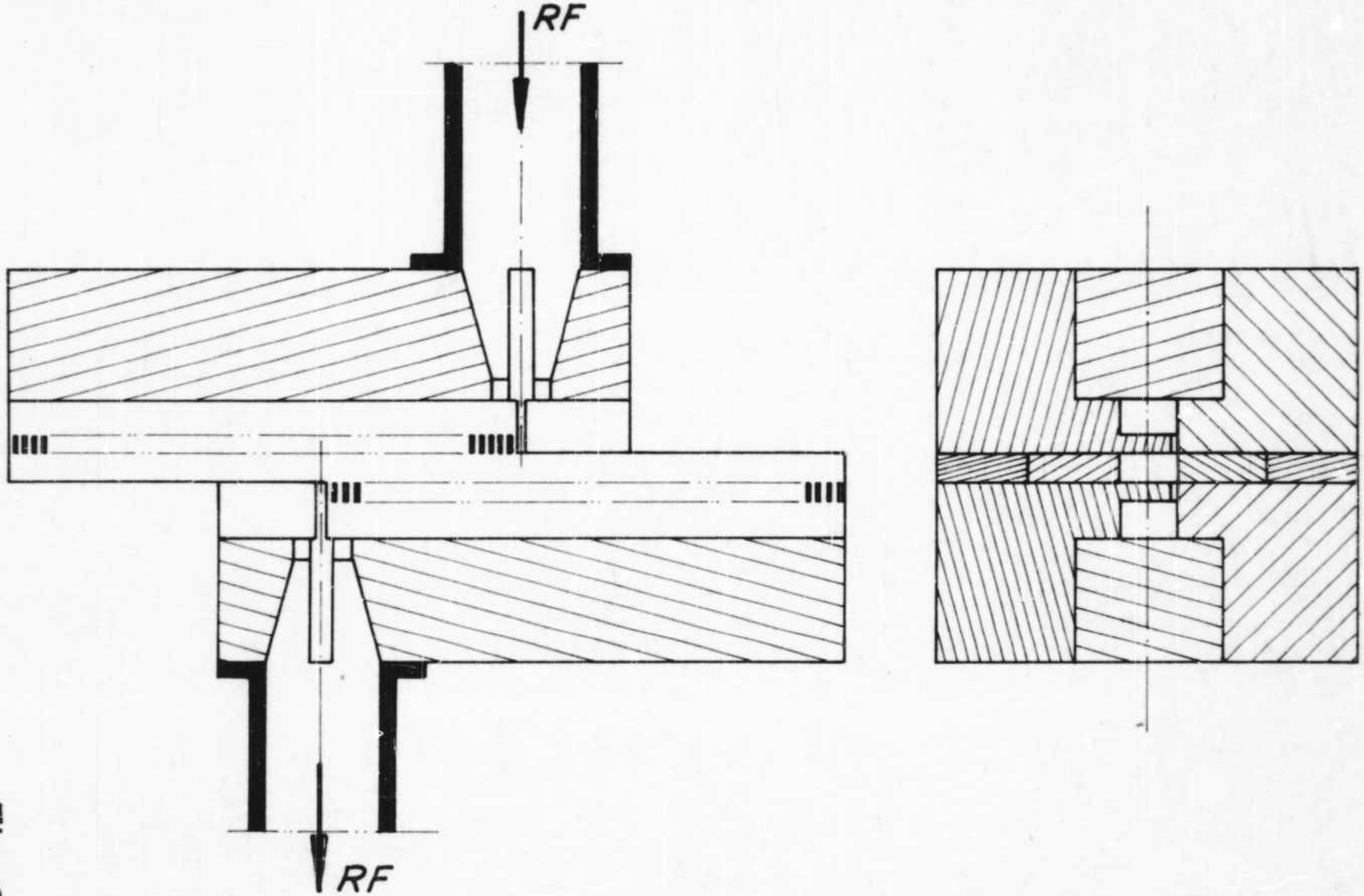


Fig. 26

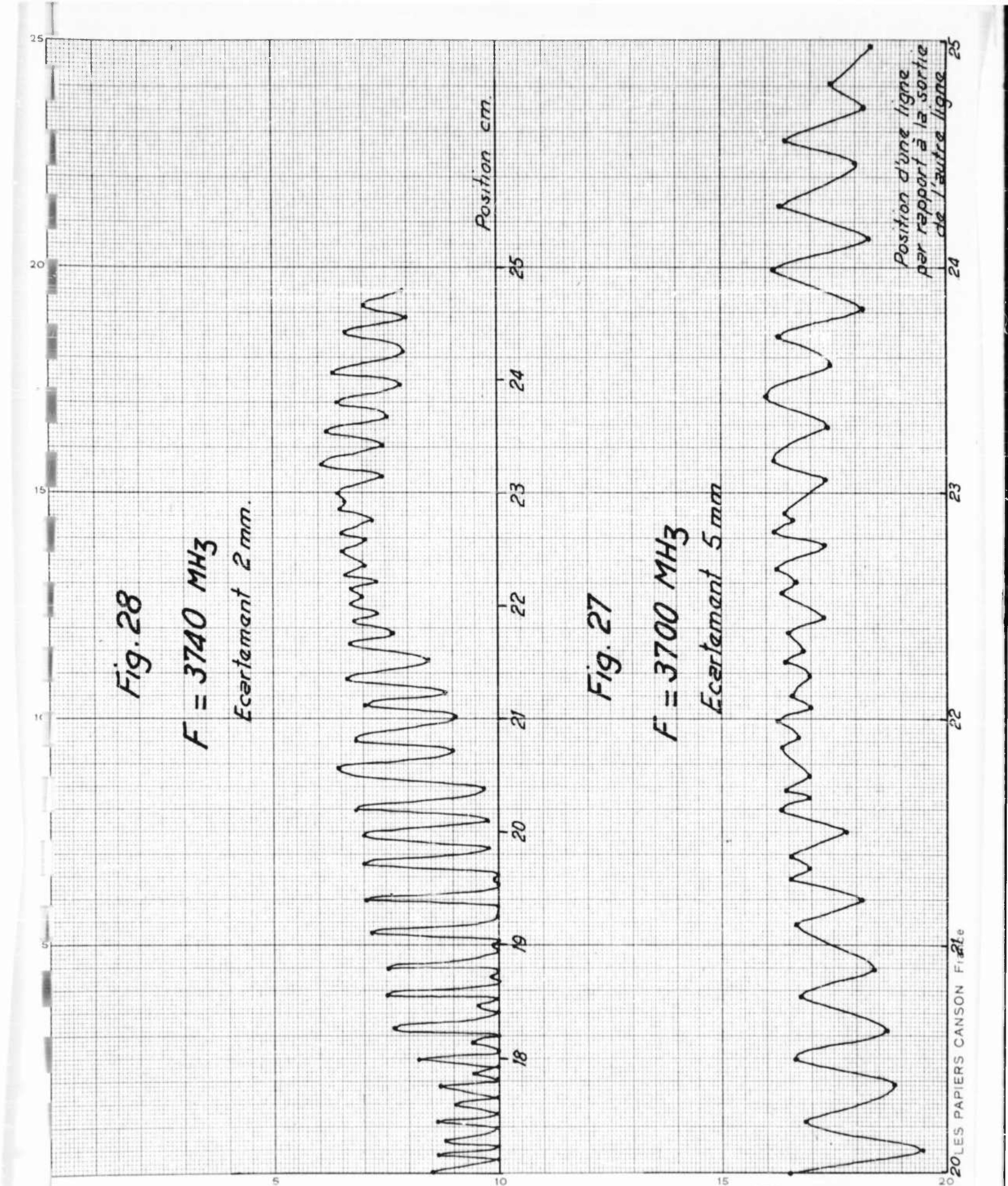


Fig. 28
F = 3740 MHz
Ecartement 2 mm.
Fig. 27
F = 3700 MHz
Ecartement 5 mm
Position cm.
Position d'une ligne par rapport à la sortie de l'autre ligne
LES PAPIERS CANSON France

Fig. 27 - 28

SCHEMATIC DIAGRAM

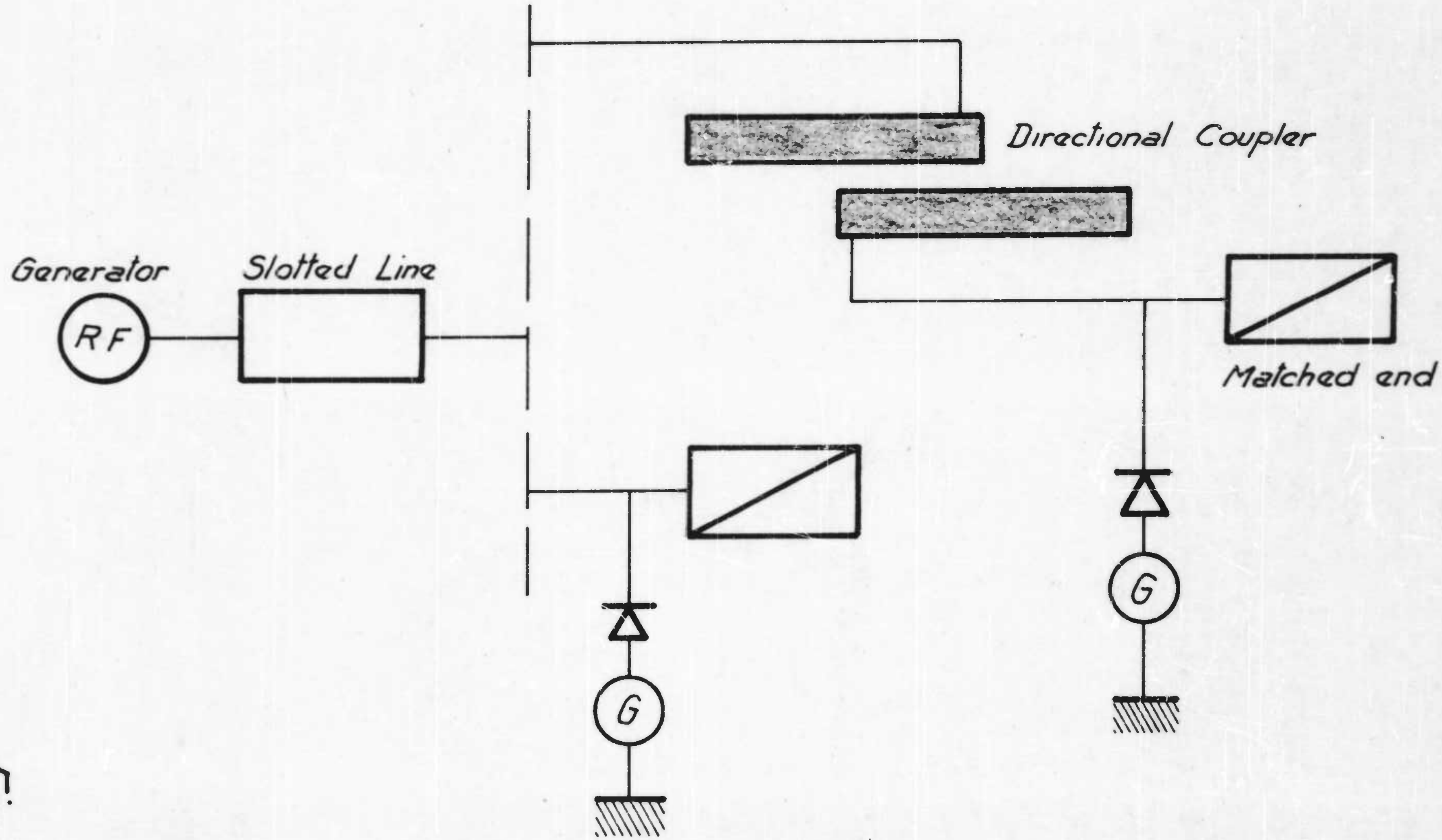
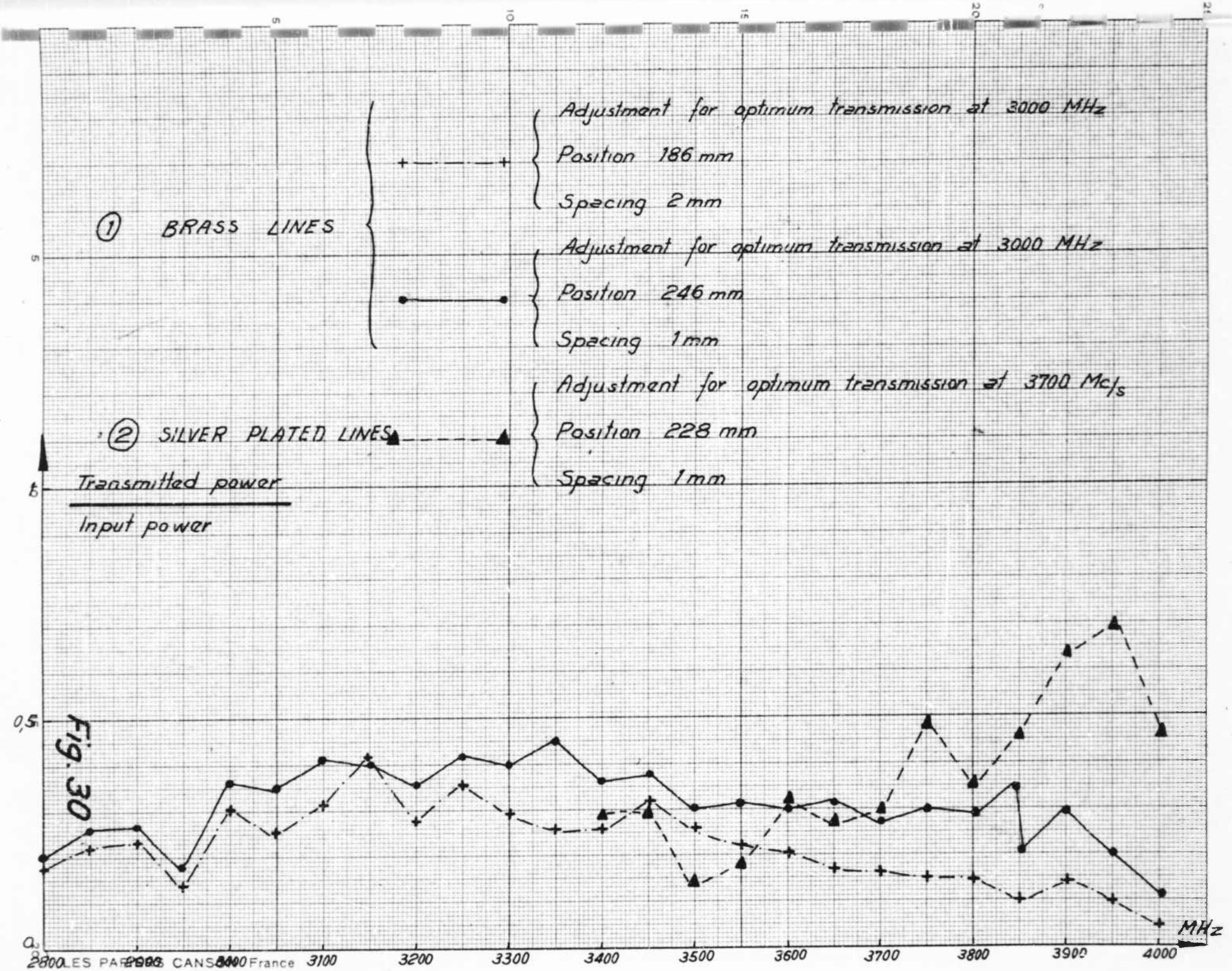


Fig. 29



① BRASS LINES
Adjustment for optimum transmission at 3000 MHz
Position 186 mm
Spacing 2 mm
Adjustment for optimum transmission at 3000 MHz
Position 246 mm
Spacing 1 mm
② SILVER PLATED LINES
Adjustment for optimum transmission at 3700 Mc/s
Position 228 mm
Spacing 1 mm
Transmitted power / Input power
0,5
MHz
2800
3100
3200
3300
3400
3500
3600
3700
3800
3900
4000

Fig. 30

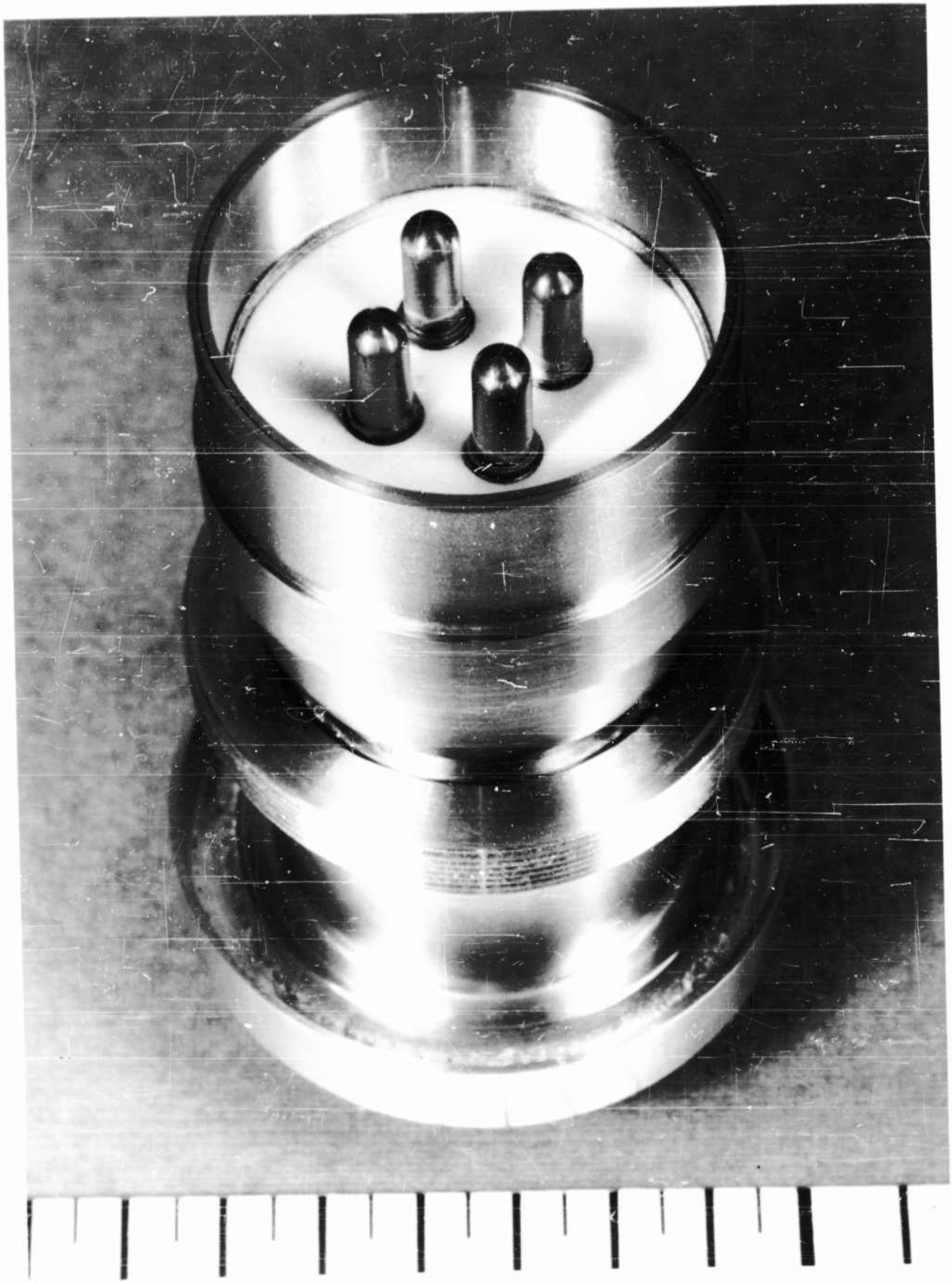


FIG. 1

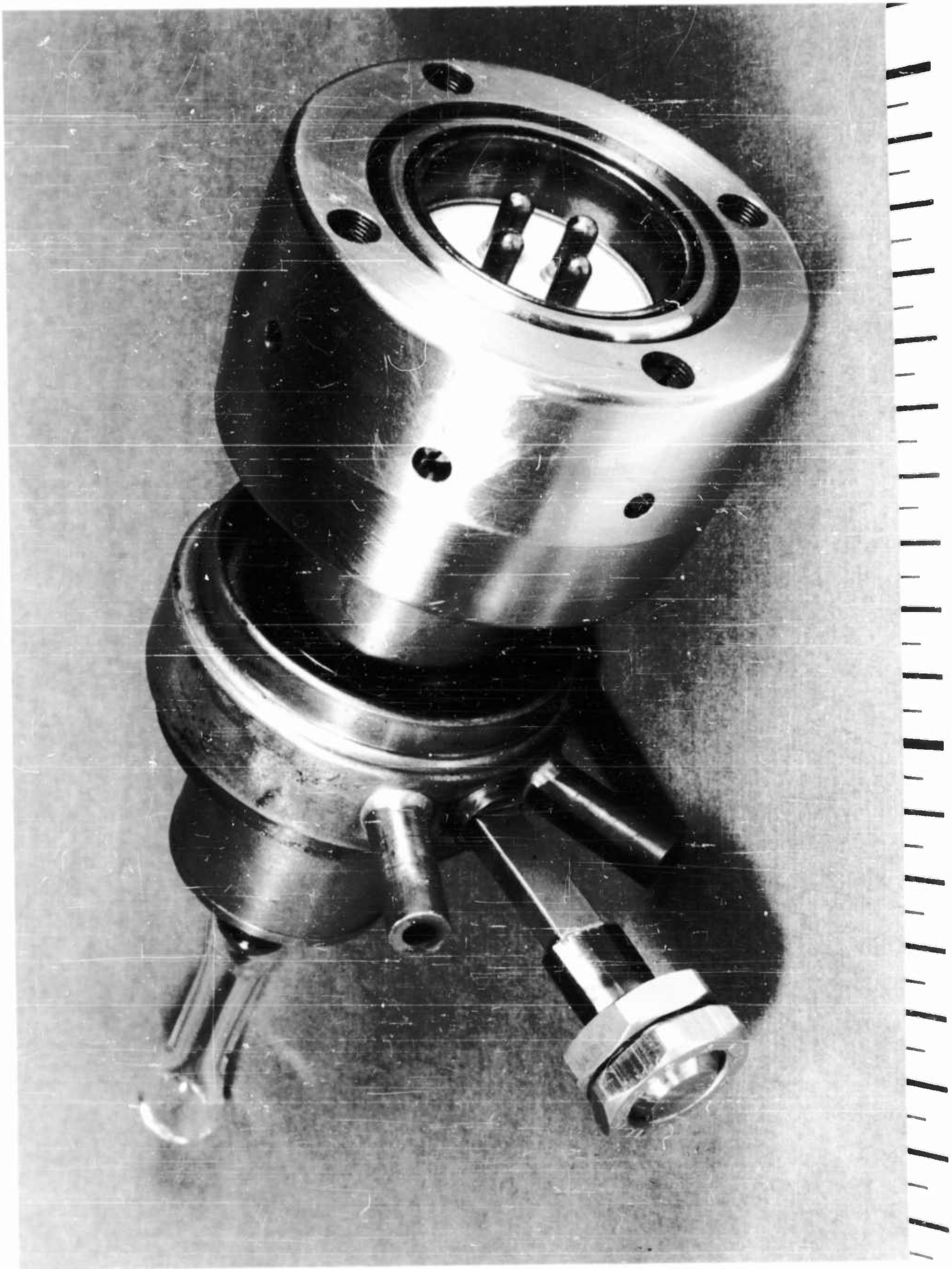


FIG. 2

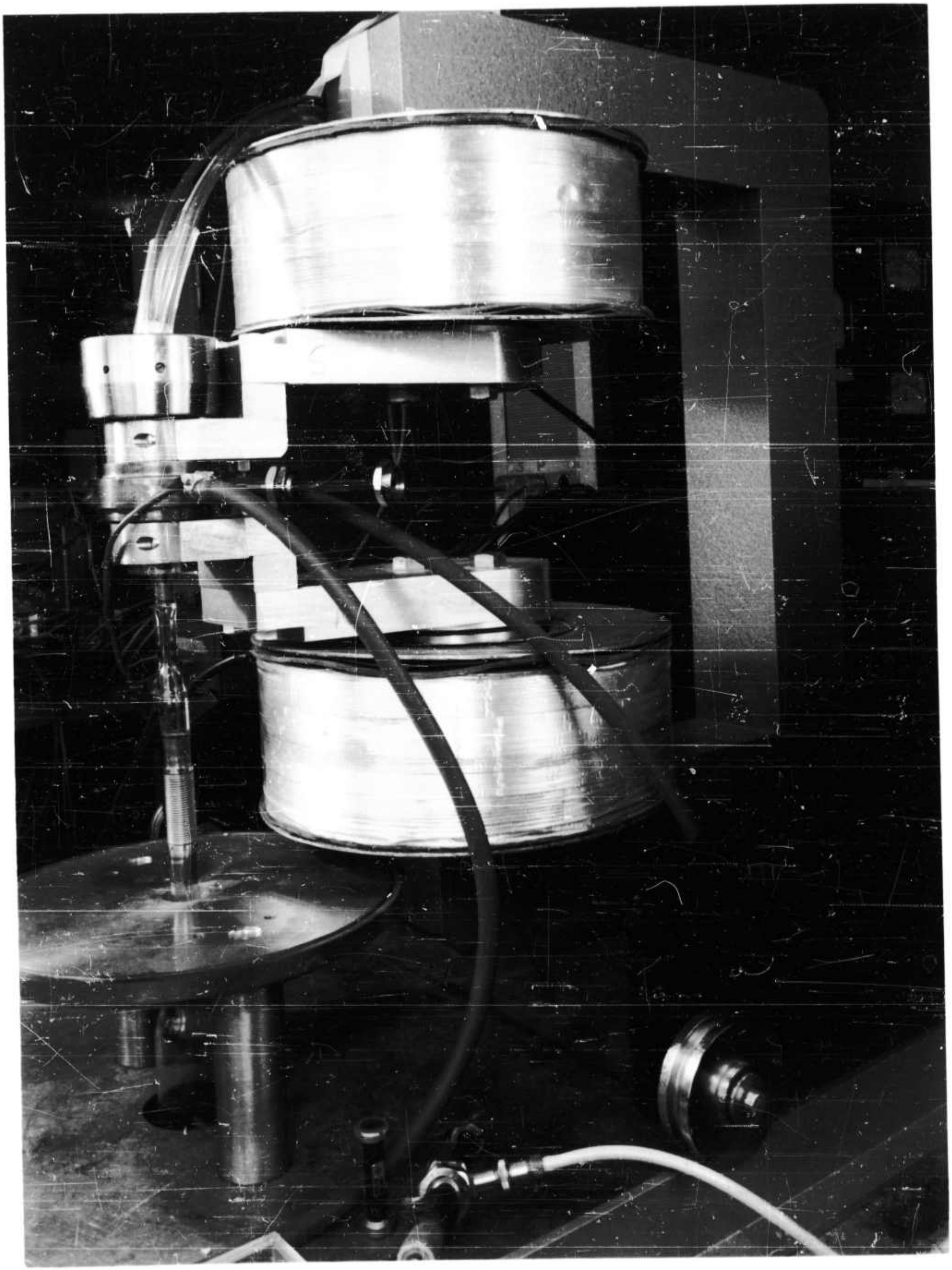


FIG. 3

FIG. 4

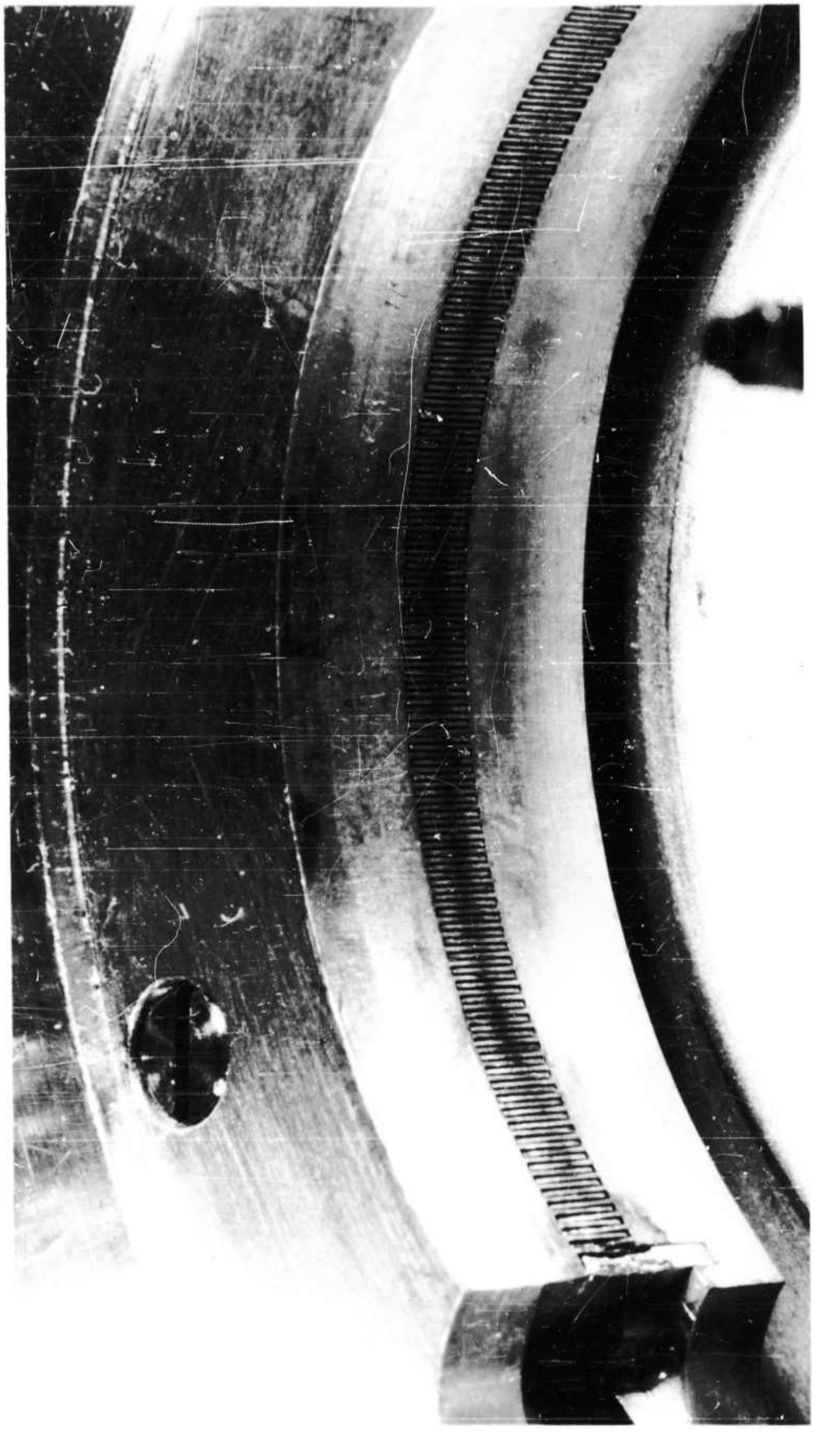


FIG. 5

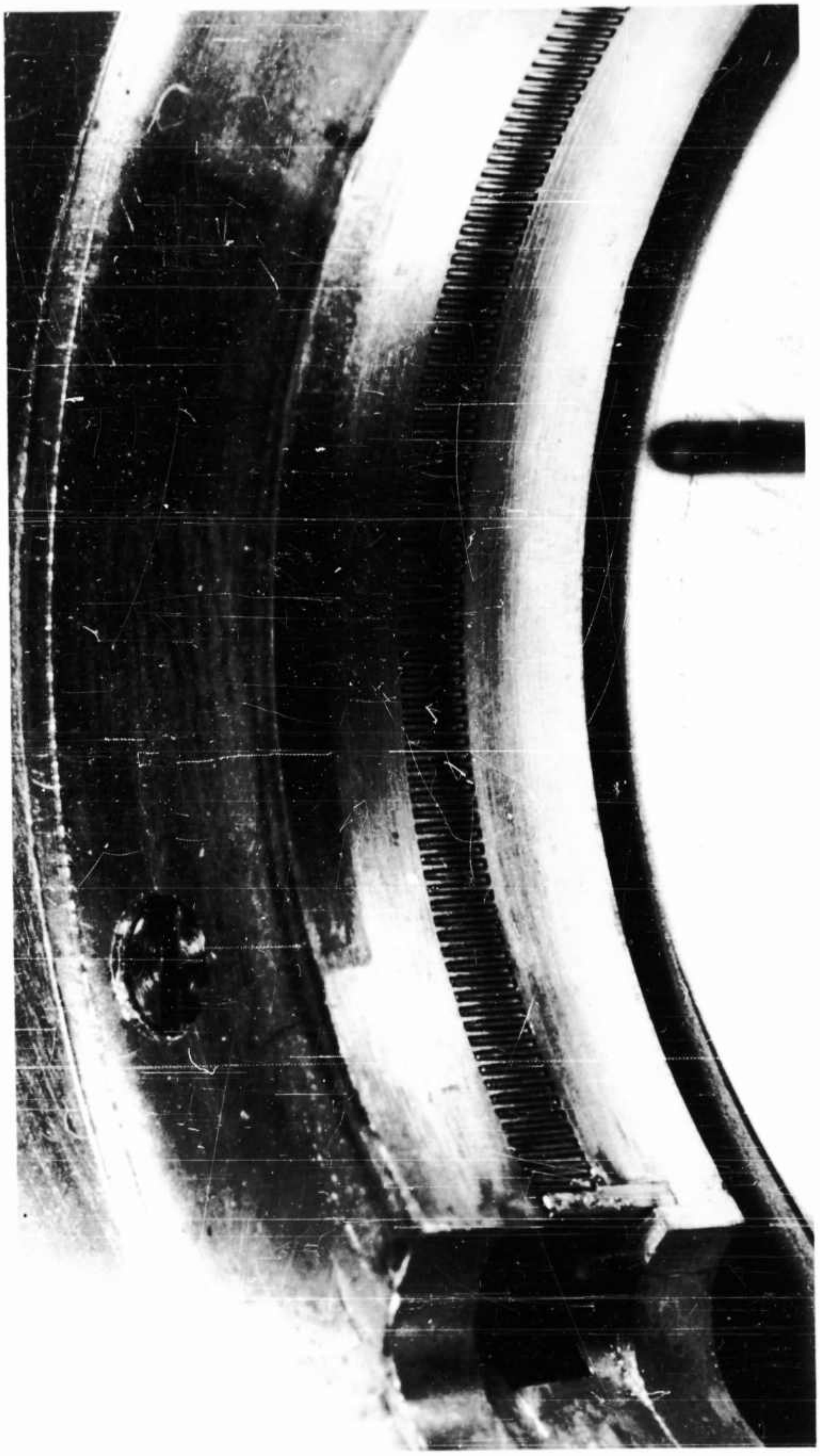


FIG. 6

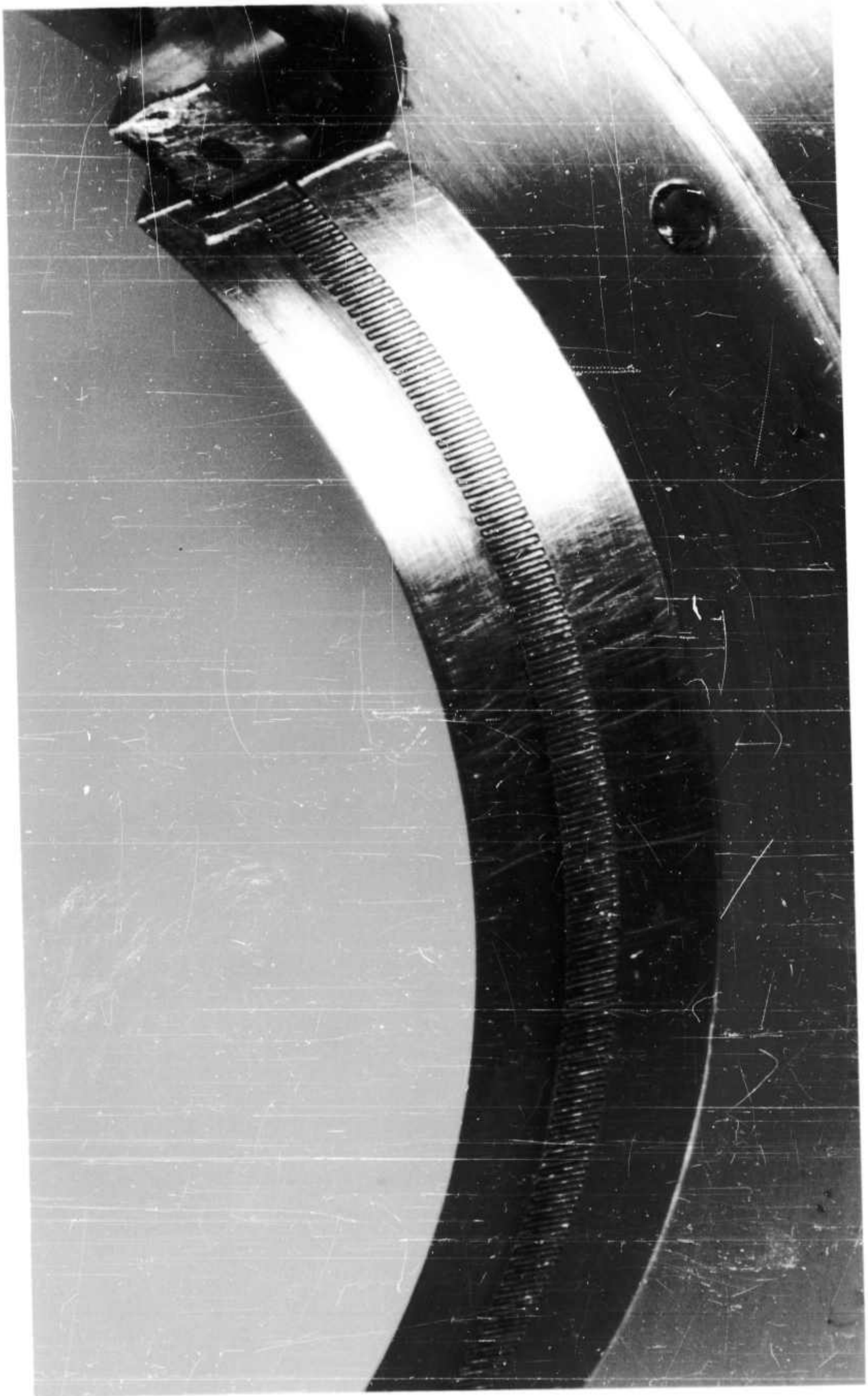


FIG. 7